MASSACHUSETTS
BAY
TRANSPORTATION
AUTHORITY

FTA GRANT NO. MA-03-0227
BLUE LINE MODERNIZATION PROJECT

CONTRACT SPECIFICATIONS
for
MBTA Contract No. S10CN04

Volume 2 of 2

Blue Line Modernization Project
Maverick Square Station
and Blue Line Vents
East Boston, Massachusetts

September, 2004

CONFORMED COPY

PROJECT MANAGER'S COPY

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SECTION 08100

METAL DOORS AND FRAMES

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing and installing hollow metal doors and frames, in accordance with Standard Specification Construction Section 08100, except as modified herein.

B. Provide standard steel doors and frames closely matching profiles and dimensions indicated.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM NO.	DESCRIPTION	UNIT
0810.000	Metal Doors & Frames	LS

-END OF SECTION-

SECTION 08305

ACCESS DOORS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies access doors in floors, roofs and walls to provide access to chases, valves, controls and equipment, and to provide access to Service Room 005 and at North End of Ventilation Shaft.

1.02 RELATED WORK

A. Carefully examine all of the Contract Documents for requirements which affect the work of this Section.

B. Other specifications sections which directly relate to the work of this section include, but are not limited to, the following:

1. Section 04200 - Unit Masonry.
2. Section 07920 - Sealants and Caulkings
3. Section 09900 - Painting
4. Division 15 - Mechanical
5. Division 16 - Electrical

1.03 INTENT

A. A major intent of the work of this section is to provide access to every chase, valve, control and item of equipment that would otherwise be inaccessible. Also, provide roof access hatch located above Service Room 005.

1.04 QUALITY ASSURANCE

A. Source: For each type of material required for the work of this section, provide primary materials which are the products of one manufacturer. Provide secondary materials which are acceptable to the manufacturers of the primary materials.

B. Sizes: Provide access doors of appropriate size for their intended use. Use manufacturer's standard sizes wherever possible.

C. Location: Verify locations of access doors with the Engineer in the field prior to installation.

1.05 TESTS

A. Fire-Resistance: Where fire-resistance ratings are indicated or required by authorities having jurisdiction, provide access doors which are identical to assemblies whose fire-resistance rating has been tested by independent agencies acceptable to the Engineer and authorities

having jurisdiction. Provide UL labeled assemblies.

1.06 SUBMITTALS

A. Product Data: Submit manufacturer's product data, installation instructions, use limitations and recommendations for each material used. Provide certifications stating that materials comply with requirements.

1.07 DELIVERY, STORAGE AND HANDLING

A. Deliver materials and products in unopened factory labeled packages. Store and handle in strict compliance with manufacturer's instructions and recommendations. Protect from damage. Sequence deliveries to avoid delays, but minimize on-site storage.

1.08 COORDINATION

A. Conference: Convene a pre-installation conference to establish procedures to coordinate this work with related and adjacent work.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Provide products of one of the following manufacturers or equal that meet or exceed the requirements of these specifications:

1. Karp Associates, Inc.
2. Meadowcraft, Inc.
3. Milcor/Inryco
4. Nystrom, Inc.
5. Bilco.
6. Dur-Red Products
7. JL Industries

2.02 MATERIALS AND PRODUCTS

A. Provide each access door assembly manufactured as a complete unit, ready for installation with all necessary parts.

1. Provide standard and/or custom stainless steel access doors where exposed to view in public spaces.

B. Provide access doors that are full welded with welds ground flush and smooth and fabricated from sheet steel as follows:

1. Frames: Minimum 16 gage galvanized steel at concealed locations, 16 gage stainless steel at public spaces, including Lobby; with 1 in. exposed flange.

2. Flush Doors: Minimum 14 gage galvanized sheet steel at concealed locations, 14 gage stainless steel at public locations; with concealed continuous piano hinge set to

open 175° or concealed spring hinges on fire-rated doors.

3. Locks/Latches: Provide at least two screwdriver operated cam latches for each door to hold door in flush, smooth plane when closed. On fire-rated assemblies, provide manufacturer's standard self-latching, fire-rated devices. In public areas, such as toilet rooms, provide keyed cylinder locks with all doors keyed the same. Provide two keys for each locked access door.

C. Access Hatch at Service Room 005: Provide 8 ft. x 12 ft., double leaf equipment hatch, equal to Dur-Red Products Model EH, or approved equal manufactured by JL Industries, Karp Associates, or approved equal. Loading shall be designed for HS25 truck loading with 30% impact.

D. Access Hatch at North End of Ventilation Shaft: Provide 3 ft.-6 in. x 3 ft.-6 in., single leaf equipment hatch, equal to JL Industries Model RFD, or approved equal manufactured by Dur-Red Products, Karp Associates, or approved equal. Loading shall be designed for HS25 truck loading with 30% impact.

2.03 FINISHES

A. Factory Primed Steel: Provide minimum 2.0 mil dry film thickness of rust-inhibiting primer which is compatible with finish paint specified in Painting Section.

B. Stainless Steel: Provide AISI No. 7.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Strictly comply with manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this section.

B. Coordinate installation with related and adjacent work. Set frames accurately into position and securely fasten truly plumb and level and in proper alignment with adjacent finishes. Set doors so that frames are in full contact with surrounding construction on entire perimeter.

3.02 ADJUSTING, CLEANING, & PROTECTION

A. Adjust operating parts to work easily, smoothly, and correctly.

B. Touch-up damaged coatings and finishes to eliminate evidence of repair.

C. Repair minor damage to eliminate all evidence of repair. Remove and replace work which cannot be satisfactorily repaired.

D. Clean exposed surfaces using materials and methods recommended by manufacturer of material or product being cleaned. Remove and replace work that cannot be successfully cleaned.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM NO.	DESCRIPTION	UNIT
0550.305	Hatches	LS

- END OF SECTION -

SECTION 08710

FINISH HARDWARE

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies finish hardware for the Project. Work includes, but is not limited to, the following:

1. Providing hardware for all doors.
2. Installing Authority-furnished lock cylinders and cores, including lock cylinders for doors, access doors, and elevator key switches.
3. Providing the services of a qualified hardware consultant to prepare detailed schedules of hardware required for the project.

1.02 RELATED WORK

A. Examine Contract Documents for requirements that affect work of this Section. Other Specification Sections that directly relate to work of this Section include, but are not limited to:

1. Section 08100, METAL DOORS AND FRAMES; Steel doors and frames.

1.03 REFERENCES

A. Comply with applicable requirements of the following standards. Where these standards conflict with other specified requirements, the most restrictive requirements shall govern.

1. American National Standards Institute (ANSI):

   A117.1Providing Accessibility and Usability for Physically Handicapped People

2. Door and Hardware Institute (DHI):

   Ref. 1 Recommended Locations for Builders Hardware

1.04 SUBMITTALS

A. Hardware Schedule: Provide six copies of final hardware and keying schedule. Format schedule vertically. List each door opening using same designations indicated on Drawings.

B. Installation Templates: Provide installation templates for work installed or prepared for installation by others.

C. Product Data: Submit manufacturer's product data, catalog cuts, descriptive data, UL listings, and other pertinent technical data for each hardware item used. Submit certifications of fire-ratings for hardware items located in rated assemblies.

D. Samples: Submit samples of each finish to be exposed. Show full range of color and finish variations expected.

1. Submit actual finished items of hardware when directed by Engineer. Acceptable items may be used in the completed work.

1.05 QUALITY CONTROL

A. Source: For each type of hardware required for the work of this section, provide products of one manufacturer.

B. Consultant: Provide the services of an accredited hardware consultant, acceptable to the Engineer, to prepare final hardware schedules and to certify that the work of this section meets or exceeds the requirements specified in this section and the requirements of authorities having jurisdiction.

C. Fire-Resistance: Where fire-resistance ratings are indicated or required by authorities having jurisdiction, provide hardware which is identical to hardware which have been labeled for fire-rated use by independent agencies acceptable to the Engineer and authorities having jurisdiction.

1.06 DELIVERY, STORAGE AND HANDLING

A. Deliver hardware in labeled packages coordinated with hardware set numbers. Store and handle in strict compliance with manufacturers' instructions and recommendations. Protect from damage and theft.

B. Sequence ordering and deliveries to avoid delays, but minimize on-site storage.

1.07 SEQUENCING AND SCHEDULING

A. Conference: Convene a pre-installation conference to establish procedures to maintain optimum working conditions and to coordinate this work with related and adjacent work.

PART 2 - PRODUCTS

2.00 GENERAL

A. One or more manufacturers are listed for each type of hardware required. Catalog numbers of the manufacturer that is underlined are used in the specifications to establish the standard of quality for each type of hardware. Provide the item specified or another product of a specified manufacturer which meets or exceeds this standard, as judged solely by the Engineer.

B. The drawings and schedules show the swing and hand of each door. Provide the proper hardware that permits the operation shown.

C. Do not permit manufacturers' trademarks or names to be displayed in a visible location on any item of hardware.

D. Base Metal: Provide hardware items of plated steel for interior work, except stainless steel, aluminum and plastic items. Provide plated brass or bronze base metal for all exterior hardware, except stainless steel and aluminum items.

E. Fasteners: Provide concealed fasteners wherever possible. Do not use through bolts unless approved by Engineer. Provide Phillips flat head screws which match finish of hardware being fastened for all visible fasteners.

2.01 MATERIALS

A. Hinges

1. Ball Bearing and Plain Hinges. Provide hinges complying with the following requirements:

a. Provide products of one of the following manufacturers or equal that meet or exceed the requirements of these specifications:

1) Hager
2) Lawrence
3) McKinney
4) H. Soss
5) Stanley

b. Provide template produced, full mortise, 5 knuckle hinges as follows:

1) For all doors with closers, provide heavy-weight, 4 ball bearing, heavyweight hinges.

2) For all other doors not listed above, provide standard weight, 2 ball bearing hinges.

3) For double swing gates, provide heavy-duty, double-acting spring hinges.

c. Hinge Height: 4-1/2".

d. Hinge Width: Consultant shall determine width based on door thickness and trim conditions. Provide minimum 4-1/2" wide hinges.

e. Quantity: Provide 3 hinges for doors up to 7'-6" high and one additional hinge for each additional 2'-6" of height. Provide one additional hinge for doors over 3'-6" wide.

2.02 LOCKS AND LATCHES

A. Provide products of one of the following manufacturers or equal that meet or exceed the requirements of these specifications:

1. Corbin
2. Sargent

3. Schlage
4. Russwin

B. Provide types and functions listed in hardware schedules.

1. Mortise Locksets and Latchsets: Unless scheduled otherwise, provide Schlage L9000 series with #06 lever handles and 2-1/2" diameter rose, or approved equal.

C. Throw: Provide 1/2" minimum, except comply with UL requirements for fire-rated hardware.

D. Strikes: Provide standard box strikes with extended curved lip and finished to match lock or latch.

E. Rabbeted Doors: If rabbeted door stiles are indicated, provide rabbeted locks and latches.

2.03 KEYING AND LOCK CYLINDERS

A. Provide interchangeable core cylinders for all locksets. Provide temporary cores for construction and remove and replace with permanent cores when directed.

B. Authority will furnish permanent cylinders and cores for installation by Contractor.

C. Metals: Provide keys made from stainless steel, brass or nickel silver.

D. Provide 3 keys for each lock, 5 master keys and 5 grandmaster keys. Provide one blank key for each lock.

E. Tag and label each key.

2.04 KEY CONTROL SYSTEM

A. Provide key control system consisting of labels, tags, card index and metal wall mounted cabinet.

B. Set up control system, label and identify each key, type index cards and deliver to Owner complete and ready for use.

2.05 BOLTS AND COORDINATORS

A. Provide products of one of the following manufacturers or equal that meet or exceed the requirements of these specifications:

1. Glynn-Johnson
2. Ives
3. EPCO

B. Flush bolt for non-rated doors: Ives 458B or 358, or equal.

C. Flush bolt for rated doors: Ives 258B or equal.

D. Coordinator: Ives 956 with 903 fillers and brackets as required or equal.

E. Carry Bars: Ives 478 or 478-1/2 or equal. Provide whenever astragal is used.

F. Flush Bolt Size: 1/2" diameter and length as necessary to keep operable hardware within 6'-6" of floor.

G. Strikes: Provide dust-proof strikes for foot bolts and standard strikes for head bolts.

2.06 EXIT DEVICES (Panic Hardware)

A. Provide products of one of the following manufacturers or equal that meet or exceed the requirements of these specifications:

1. Adams Rite
2. Monarch
3. Sargent
4. Von Duprin
5. Yale

B. Provide series Von Duprin 33 or equal.

C. Where scheduled, provide lever handle outside trim with cylinder lock and function so that key in cylinder locks or unlocks outside lever.

D. Provide mortise locks for single doors.

E. Except for fire-rated doors, provide keyed dogging feature.

2.07 CLOSERS

A. Provide products of one of the following manufacturers or equal that meet or exceed the requirements of these specifications:

1. LCN
2. Norton
3. Sargent
4. Yale

B. Provide the following types, or equal:

1. Provide LCN 4030/4130 series for low frequency interior doors.

2. Provide LCN 4011/4111 series for toilet room entrances, entry doors, stair doors, smoke and fire doors, and exterior doors not indicated to be another type.

3. Provide LCN 2030 series where noted as "concealed" in thin [1-3/4" x 4" minimum metal transom bars or head frames. Provide LCN 2010 series where noted as "concealed" in deep [4" x 4" minimum] wood or metal transom bars or head frames.

4. Provide LCN 1000 series closers, where indicated as "utility type".

5. Provide hold-open feature where indicated.

6. Wherever possible, mount closers on least public side of door (pull side of toilet rooms). Provide closers with parallel arms wherever closers are on the stop side of doors which swing out into corridors and public areas. Provide closers that do not intrude into door opening.

C. Follow manufacturer's recommendations for size of closer based on size of door, exposure and frequency of use. Where parallel arms are used, provide closers which are one size larger than recommended.

D. Provide barrier-free closers which comply with UFAS requirements and requirements of the Massachusetts Architectural Barriers Board for opening force and delayed action closing.

E. Where indicated, provide closers with built in door stop function at an adjustable angle.

2.08 DOOR TRIM UNITS

A. Provide products of one of the following manufacturers or equal that meet or exceed the requirements of these specifications:

1. Brookline
2. Cipco
3. Hiawatha

B. Provide push plates, protection plates and kickplates which are beveled on all four sides.

C. Protection and Kickplate Width: 1/2" less than door width, except 1-1/2" less than door width when on stop side.

D. Protection and Kickplate Height: 42" high protection plate; 10" high kickplate.

E. Push Plate Size: As required to fit double-swing gates at 189 State Street.

F. Material: 18 gage solid metal closely matching lockset/latchset finish. Plated metal door trim units are not acceptable.

2.09 STOPS

A. Provide products of one of the following manufacturers or equal that meet or exceed the requirements of these specifications:

1. Ives
2. Brookline
3. Cipco
4. Glynn-Johnson

B. Provide Ives wall stops 406, 407 or 408 to suit wall condition or equal. Where indicated or where wall stop not practical, provide Ives floor stops 436 or 438 to suit floor conditions and clearances or equal. Provide carpet risers as required.

2.10 WEATHERSTRIPPING & THRESHOLDS

A. Provide products of one of the following manufacturers or equal that meet or exceed the requirements of these specifications:

1. Reese
2. National Guard Products
3. Pemko
4. Zero

B. Thresholds: Provide thresholds from one of the specified manufacturers that has a profile that closely matches those indicated on Drawings, or as recommended by manufacturer to suit conditions and access codes.

C. Weatherstripping: Provide Reese 430 or 372 drop seal and 811 weatherstripping or equal. Provide weatherstripping for every exterior door, doors with unheated spaces on one side and wherever scheduled. Weatherstripped doors are required to provide a continuous seal at the entire perimeter of door with no cracks.

2.11 MISCELLANEOUS HARDWARE

A. Provide products of one of the following manufacturers or equal that meet or exceed the requirements of these specifications:

1. Reese
2. National Guard Products
3. Pemko
4. Zero

B. Astragals: Provide Reese no. 87 or equal.

C. Silencers: For steel frames, provide grey resilient silencers to suit frame type. Provide 3 for single doors and 2 for pair doors.

2.12 FINISHES

A. Provide US 32D dull stainless steel for all hardware.

B. Provide stainless steel covers on closers.

PART 3 - EXECUTION

3.01 INSPECTION

A. The Installer shall examine doors, frames and conditions under which this work is to be performed and notify Contractor, in writing, of conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning work means Installer accepts substrates and conditions.

3.02 INSTALLATION

A. Strictly comply with manufacturers' instructions and recommendations, except where more restrictive requirements are specified in this section.

B. Mount hardware at locations indicated in Door and Hardware Institute Recommended Locations for Builders Hardware for Standard Steel Doors and Frames, except where specifically indicated otherwise or required by authorities having jurisdiction.

C. For special or custom doors follow recommendations of DHI Recommended Locations for Builders Hardware for Custom Steel Doors and Frames and consult Engineer.

D. Set hardware plumb, level and in exact alignment and location. Conceal and countersink fasteners wherever possible.

E. Set thresholds in full bed of butyl-rubber or polyisobutylene mastic.

3.03 ADJUSTING, CLEANING, & PROTECTION

A. Adjust operating parts to work easily, smoothly, and correctly.

B. Clean exposed surfaces using non-abrasive materials and methods recommended by manufacturer of hardware being cleaned. Remove and replace work that cannot be successfully cleaned.

C. Provide temporary protection to ensure work being without damage or deterioration at time of final acceptance. Remove protections and reclean as necessary immediately before final acceptance.

3.04 HARDWARE SCHEDULE

A. HS-1 For Door Nos. 101, 101A; 101B; 102.

2 pr.	Butt Hinges
1	Mortise Exit device, classroom function with dogging, key exterior trim
1	Exterior Pull handle
1	Floor Closer with backchecking
	weatherstripping
	threshold

B. HS-2 For Door Nos. 01; 02; 03A; 04A; 04B; 05; 06; 07; 08; 09; 10; 11; 11A; 12; 12A; 17; 18; 19; 20; 22; 23; 24; 25; 26; 27; 28; 32; 33; 34; 35.

1-1/2 pr.	Butt Hinges
1	Mortise Lockset, Storeroom Function
1	Closer
1	Stop
2	kickplates (one each side of door)
	Silencers

C. HS-3 For Door Nos. 13; 31.

1-1/2 pr. Butt Hinges
1 Mortise Lockset, Office Function
1 Closer
1 Stop
Silencers

D. HS-4 For Door Nos. 15; 16.

1-1/2 pr. Butt Hinges
1 Mortise Lockset, Privacy Function
1 Closer
1 Stop

E. HS-5 For Door No. 14.

1-1/2 pr. Butt Hinges
1 Mortise Latchset, Passage Function
1 Stop
Silencers

F. HS-6 For Door Nos. 03; 04; 11B; 21; 35A.

3 pr. Butt Hinges
1 Mortise Lockset, Storeroom Function
1 set Flushbolts
2 Stops
4 kickplates (one each side of each door)
Silencers

3.05 HARDWARE SCHEDULE FOR UNIT SUBSTATION B-2

A. HS-1* For Door No. 101 and 104

1-1/2 Pr. Hinges, CB 1961
1 Panic Device, 9975 L x 03
1 Closer, LCN 4110 / 110° stop
1 Threshold, Pemko 2005 AS
1 Weatherstrip, Pemko 319 CN
1 Lock Guard, Ives LG1
3 Silencers

B. HS-2* For Doors 102 and 103

All door hardware by door manufacturer (existing to be reused)

C. HS-3* For Door 105

1-1/2 Pr. Hinges, CB 1961
1 Lockset, L9080 x 03

1	Closer, LCN 4110/ 110° stop
1	Threshold, Pemko 2005 AS
1	Weatherstrip, Pemko 319 CN
1	Lock Guard, Ives LG1
3	Silencers

3.06 HARDWARE SCHEDULE FOR VENTSHAFT B3 AND B5

A. HS-1** For Doors 1, 3, 6, and 8

1 Pr	Hinges, CB1960
1	Lockset, L9080 x 03
1	Closer 4110
1 Set	Gasketing, Pemko 319CN
1	Lock Guard, Ives LG1(Doors 1 and 8 only)
3	Silencers

B. HS-2** For Doors 2 and 9

3 Pr	Hinges, CB1961
1	Panic Device 9947 L x 03 on active leaf, RH Door
1	Full Dummy Trim L0172 on inactive leaf, LH Door
1	Closers 4110 on active leaf
1	Set Manual Flush Bolts, Ives FB458
1	Threshold, Premko 179 AT
1 Set	Gasketing, Pemko 319CN
1	Overlapping Astragal, Ives 357SS with S88
2	Silencers
1	Sign on active door leaf inside Fan Room "Caution This Door Opens Into Train Right Of Way"

C. HS-3** For Doors No. 4,5,7,10,11 and 12

1-1/2 Pr.	Hinges, CB 1961
1	Lockset, L9080 x 03
1	Closer, LCN 4110 / 110° stop
1	Threshold, Pemko 179 AT
1 Set	Gasketing, Pemko 319 CN
1	Lock Guard, Ives LG1
3	Silencers

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM NO.	DESCRIPTION	UNIT
0865.045	Hardware	Lump Sum

- END OF SECTION -

SECTION 08800

GLAZING

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies all glass and glazing, in accordance with Standard Specifications Section 08800, except as modified herein.

1.03 SUBMITTALS

A. Product Data: Submit manufacturer's product data, installation instructions, use limitations and recommendations for each material used. Provide certifications stating that materials comply with requirements.

1. Warranties: Submit example copies of manufacturer's warranties before ordering materials.

D. Calculations: Provide glass manufacturer's windload charts, calculations and certification of the performance of this work. Show how design load requirements and other performance criteria have been satisfied.

E. Verification Samples: Submit representative samples of each glass and glazing material that is to be exposed in the finished work, showing the full range of color and finish variations expected. Provide glass samples having minimum area of 144 square inches and 12" long samples of sealant and glazing materials. Samples of single thickness, non-fabricated clear glass are not required.

F. Test Reports: Submit certified reports for tests required.

1.06 INTENT AND PERFORMANCE REQUIREMENTS

A. A major intent of the work of this section is to be weathertight and keep the building dry. Work of this section shall withstand normal loads due to wind, temperature and normal impact without failure, breakage of glass or seals, fogging or other defects.

1. Temperature Range: Glass and glazing shall function correctly and normally throughout an ambient temperature range of 100°F above and below installation temperature.

2. Laminated Glass: Laminated glass shall be free from delamination, edge separation, visual discoloration, and other damage throughout the warranty period.

4. Coated Glass: Coated glass shall be free from peeling, cracking, hazing, visual non-uniformity, and other defects throughout the warranty period.

1.07 QUALITY ASSURANCE

A. Source: For each type of glass and glazing material required for the work of this section, provide primary materials which are the products of one manufacturer. Provide secondary materials which are acceptable to the manufacturers of the primary materials. All glass of each type shall exactly match.

B. Glass Thickness: Determine exact sizes and thickness of glass products and certify that the work of this section meets or exceeds the performance requirements specified in this section. Provide proper thickness, edge clearances and tolerances to comply with the recommendations of the glass manufacturer. Provide thickness required for application indicated.

C. General Standards: Comply with recommendations of Flat Glass Marketing Association *Glazing Manual* and *Sealant Manual.*

D. Safety Glass Standards: Provide safety glass which complies with ANSI Z97.1 and requirements of 16 CFR Part 1201 for Category II materials and is permanently marked with certification label of Safety Glass Certification Council.

E. Primary Glass Standards: Comply with FS DD-G-451 requirements for type, quality, class and form.

F. Heat-Treated Glass Standard: Comply with FS DD-G-1403 requirements for type, quality, class and form.

1.08 TESTS

A. Preconstruction Sealant Tests for Adhesion and Compatibility: Submit samples of every material to be used in the work including, but not limited to, glass, gaskets, glazing materials, framing members, and all other components and accessories, to glazing sealant manufacturer to verify sealant compatibility and to determine, by testing according to ASTM C794, if primers and what type of primers are required to ensure adhesion to substrates.

1. Schedule sufficient time for testing, analysis and reporting of results, understanding that long lead times are required by the sealant manufacturer.

2. Obtain manufacturer's written report and recommendations regarding proper sealant choice and use.

1.09 DELIVERY, STORAGE AND HANDLING

A. Deliver materials and products in labeled, protective packages. Store and handle in strict compliance with manufacturer's instructions and recommendations and FGMA 1980 Handbook.

1. Protect from all possible damage.
2. Keep shipping containers closed when not in use.
3. Protect materials during storage from moisture, sunlight, excess heat, sparks and flame.
4. Carefully store materials to avoid overloading any building component or structure.

5. Provide adequate ventilation to prevent build-up of dangerous solvent concentrations.
6. Use clean gloves and tools when handling materials. Avoid contamination.
7. Use rolling blocks and suction cups to move glass units not in shipping crates.
8. Sequence deliveries to avoid delays, but minimize on-site storage.

1.10 PROJECT CONDITIONS

A. Weather: Perform work only when existing and forecasted weather conditions are within the limits established by manufacturers of the materials and products used.

B. Temperature Limits: Install sealants only when temperatures are within the recommended range established by sealant manufacturer and never below 40°F.

1.11 WARRANTIES

A. General: Warranties shall be in addition to, and not a limitation of, other rights the Owner may have under the Contract Documents.

B. Manufacturer's Special Project Warranty on Laminated Glass: Provide written warranty signed by manufacturer of laminated glass agreeing to furnish f.o.b. point of manufacture, freight allowed project site, within specified warranty period indicated below, replacements for those laminated glass units which develop manufacturing defects. Manufacturing defects are defined as edge separation or delamination which materially obstructs vision through glass.

1. Warranty Period: Manufacturer's standard but not less than 4 years after date of substantial completion.

1.12 ATTIC STOCK

A. Provide two (2) extra curved glass roofing panels to the Authority for future repairs/replacements for the North Headhouse roof. The attic stock shall be carefully wrapped and protected, clearly labeled, and delivered and stored on site at locations as directed by the Engineer.

PART 2 - PRODUCTS

2.00 ACCEPTABLE MANUFACTURERS AND FABRICATORS

A. Provide products of one of the following manufacturers that meet or exceed the requirements of these specifications, or Engineer approved equal:

1. AFG Industries
2. Ford Glass Division
3. Guardian Industries
4. Libbey-Owens-Ford
5. PPG Industries
6. Viracon, Inc.
7. Solar Seal

2.01 GLASS MATERIALS

A. Clear Heat Strengthened Glass: Provide ASTM C1048, Condition A, Type I, Class 1, Quality q3, kind HS.

B. Clear Tempered Glass: Provide ASTM C1048, Condition A, Type I, Class 1, Quality q3, kind FT.

C. Laminated glass for glass headhouses, shall be as follows: Laminated tempered safety glass, as specified above, coated with manufacturer's proprietary, self-cleaning coating, equal to "Activ™", as manufactured by Pilkington, or approved equal. Thickness shall be as follows:

1. Walls: Laminated with two (2) layers of 1/4 in. tempered glass;
2. Roofs: Laminated with two (2) layers of 3/8 in. tempered glass, with ceramic frit applied on inside surface in patterns and colors selected by Engineer;

2.03 GLAZING MATERIALS

A. General Glazing Requirements: Provide sealants and gaskets which have performance characteristics suitable for applications intended. Make sure that glazing sealants are compatible with sealants used in insulated glass fabrication, with laminated glass interlayer, and with surfaces to be in contact.

1. Colors: Provide colors of sealants and gaskets as selected by Engineer from manufacturer's standards.

B. General Glazing Sealant, Butt Glazing, and Cap Bead Sealant: Provide sealant compatible with all substrates and materials and having maximum Shore A hardness of 50. Provide one of the following products if they meet or exceed the requirements of these specifications:

1. Dow Corning 795
2. General Electric Silglaze II.
3. Tremco Proglaze

C. Weather Seal Silicone Sealant: Provide non-acid curing sealant having movement range of ± 50% when tested according to ASTM C719. Provide one of the following products if they meet or exceed the requirements of these specifications:

1. Dow Corning 795
2. General Electric UltraGlaze 4000
3. Tremco Spectrem 2

D. Preformed Glazing Tape: Provide butyl-polyisobutylene rubber with 100% solids content in extruded tape roll form and complying with AAMA 804.1. Provide one of the following products if they meet or exceed the requirements of these specifications:

1. Protective Treatments 303 or 606
2. Tremco Preshimmed 440
3. Woodmount Chem-Tape 40

E. Gaskets and Weatherstrips: Provide extruded black sponge gaskets conforming to ASTM C509 with Shore A Durometer hardness of 40 ±5 and 20% to 35% compression. Provide black extruded dense gaskets conforming to ASTM C864 with Shore A Durometer hardness of 75 ±5 for hollow profiles and 60 ±5 for solid profiles. Provide neoprene outdoor gaskets and neoprene or EPDM indoor gaskets. Injection mold all corners of gaskets where compatible with installation procedures. Design interior and exterior gasket profiles to produce a glass edge pressure of not less than four pounds per linear inch and not more than ten pounds per linear inch.

F. Setting Blocks: Provide dense extruded neoprene or silicone with a hardness of 85 ±5 Shore A Durometer hardness, a minimum length of 4" and a minimum width equal to the glass thickness. Provide materials as recommended and approved by glass and sealant manufacturers. Provide products certified by their manufacturers to be "silicone compatible".

1. Shims: Used with setting blocks shall be the same material, hardness, length and width as setting blocks.

2. Structural Silicone Glazing: Provide silicone setting blocks where structural silicone occurs at the sill and for insulating units with silicone edge seals. Neoprene setting blocks are acceptable only if permitted by the insulating glass fabricator and if structural silicone does not occur at the sill.

G. Side Blocks: Provide dense extruded neoprene or silicone with a hardness of 55 ±5 Shore A Durometer hardness. Provide block with sufficient length to prevent point loading on the glass. Provide materials as recommended and approved by glass and sealant manufacturers. Provide products certified by their manufacturers to be "silicone compatible". Provide silicone side blocks for insulating units with silicone edge seals. Neoprene side blocks are acceptable only if permitted by the insulating glass fabricator.

H. Sealant Backer Rods: Provide flexible, resilient polyethylene foam, urethane foam, or extruded silicone as recommended and approved by sealant and glass manufacturers.

I. Primers: Provide cleaners, primers and sealers as recommended by glass and sealant manufacturers.

PART 3 - EXECUTION

3.02 PREPARATION

E. Strictly comply with manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this section. Comply with FGMA *Glazing Manual*. Do not glaze when ambient temperature is below 40°F.

1. Inspect all glass before installation. Do not install defective glass.
2. Check glass for correct size and squareness. Adjust frame or glass size to correct as necessary.
3. Protect glass from edge damage. Use roller blocks. Replace all damaged or weakened glass.
4. Thoroughly clean glazing channels and pockets immediately before glazing and keep them dry.
5. Remove coatings which are not firmly bonded to substrates. Remove lacquer, if any.

3.03 INSTALLATION

A.

9. Install tapes and gaskets to eliminate dirt and moisture pockets. Prepare for exterior cap seal.
10. Miter and seal tapes and gaskets at corners and seal at joints. Do not overlap at corners.
11. Install tapes and gaskets to prevent pulling away from corners.
12. Prevent metal to glass contact. Protect edges of insulating units from solvents and damage.
13. Replace stops and clean and prime stops, framing, and glass on both sides.

D. Sealant Application

5. Cap seal all exterior joints between glazing and framing with clear liquid sealant.
6. Cap seal with a uniform fillet sealant joint having proper bite on both glass and framing.
7. Clean, prime and mask for liquid sealants immediately before sealant application.
8. Apply wet sealant in continuous motion and tool thoroughly to "wet" contact surfaces uniformly.
9. Slope sealant to promote drainage away from glass and sealant.
10. Defer glazing of openings needed for construction operations until directed.

3.06 GLASS SCHEDULE

A. The following numerical indications of glass type are used on the drawings:

1. 1/2 in. clear tempered laminated glass at elevators, and elsewhere as indicated.
2. Glass Types for Glass Headhouses:

   a. Walls: Laminated with two (2) layers of 1/4 in. tempered glass;
   b. Roofs: Laminated with two (2) layers of 3/8 in. tempered glass, with ceramic frit applied on inside surface in patterns and colors selected by Architect;

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL No separate measurement or payment will be made for work required under this Section. All costs in connection therewith will be considered incidental to the item of work to which they pertain.

-END OF SECTION-

SECTION 08910

CUSTOM ENTRANCES, GLASS WALLS, AND BENT GLAZED ROOF

PART 1 GENERAL

1.01 DESCRIPTION

A. This Section specifies the following:

1. Custom stainless steel entrance doors.
2. Custom bent glass glazing system at headhouse roof.
3. Custom glass glazing system at entrance canopies.
4. Exterior glass wall system.
5. Glass and glazing for work of this Section.
6. Flashing and sheet metal for work of this Section.

B. Work of this Section also includes all lead-coated copper flashing and batten caps, and as specified under related Section 07600, FLASHING AND SHEET METAL WORK.

1.02 RELATED WORK

A. Examine Contract Documents for requirements that affect work of this Section. Other Specification Sections that directly relate to work of this Section include, but are not limited to:

1. Section 04450, Stone Work.
2. Section 05100, Structural Steel.
3. Section 05500, Miscellaneous Metal.
4. Section 05700, Ornamental Metalwork
5. Section 07600, Flashing and Sheet Metal Work.
6. Section 08800, Glass and Glazing.

1.03 SUBMITTALS

A. Product Data: Submit manufacturer's printed product data, specifications, details, installation instructions, use limitations and recommendations for each material used. Provide certifications that work complies with specified requirements.

B. Shop Drawings: Provide large scale shop drawings for fabrication, installation, and erection of all parts of the work. Provide plans, elevations, and details of anchorages, connections and accessory items. Provide installation templates for work installed by others. Show all interfaces and relationships to work of other trades.

C. Initial Selection Samples: Submit samples showing complete range of colors, textures, and finishes available for each material used.

D. Verification Samples: Submit representative samples of each material that is to be exposed in the completed work. Show full color ranges and finish variations expected. Provide samples having minimum size of 144 sq. in.

E. Provide a minimum 48 in. long sample of the lead coated copper batten cap system, showing soldered connections at ridge, and the soldered end cap.

1.04 QUALITY ASSURANCE:

A. Source: For each material type required for the work of this Section, provide primary materials that are the product of one manufacturer. Provide secondary or accessory materials which are acceptable to the manufacturers of the primary materials.

B. Mock-Ups: Prior to commencing the primary work of this Section, provide mock-up of one bay at locations acceptable to Engineer. Obtain Engineer's acceptance of visual qualities. Protect and maintain accepted mock-ups throughout the remainder of the work of this section to serve as criteria for acceptance of the work. Mock-up shall include one bay showing steel frame, metal finishes, glass and glazing, and lead-coated copper glazing cap.

1.05 TESTS AND PERFORMANCE REQUIREMENTS

A. Manufacturer's Standard Tests: Provide manufacturer's standard test data showing compliance with specified requirements. Provide specified tests if manufacturer's standard units have been modified, or when custom work are used.

B. Design Wind Pressure: 35 pounds per square foot.

C. Thermal Movement: Provide window systems that allow for expansion and contraction of members throughout an ambient temperature range of 100°F.

D. Field Leakage Test: The Authority reserves the right to employ an independent testing agency to perform in-place field tests for water leakage. Field test will include a prolonged water spray test. Any uncontrolled water leakage will be considered a failure. Contractor shall pay for all remedial work and all retesting due to failures.

1.06 PROJECT CONDITIONS

A. Weather: Perform work of this Section only when existing or forecasted weather conditions are within the limits established by manufacturers of the materials and products used.

B. Substrates: Proceed with work only when substrate construction and penetration work is complete.

1.07 DELIVERY, STORAGE AND HANDLING

A. Deliver materials and products in unopened, factory labeled packages. Store and handle in strict compliance with manufacturer's instructions and recommendations. Store under cover and protect from weather damage.

B. Sequence deliveries to avoid delays, but minimize on-site storage.

1.08 WARRANTIES

A. Laminated Glass Warranty: As specified under Section 08800, Glass and Glazing.

1.09 ATTIC STOCK

A. Provide two (2) extra curved glass roofing panels to the Authority for future repairs/replacements for the North Headhouse roof. The attic stock shall be carefully wrapped and protected, clearly labeled, and delivered and stored on site at locations as directed by the Engineer.

PART 2 - PRODUCTS

2.01 MATERIALS AND PRODUCTS

A. Profiles: Provide entrance doors, glass wall system, glass canopies, and bent glass glazed roof systems closely matching profiles and appearances shown. Provide systems glazed from the exterior.

B. Entrance Doors: Provide custom fabricated stainless steel entrance doors and frames matching dimensions and profiles indicated, fabricated from stainless steel plate and tubes, and as follows:

1. Tubing: ASTM A 554, Grade MT 316.
2. Pipe: ASTM A 312, Grade TP 316.
3. Castings: ASTM A 743, Grade CF 8M or CF 3M.
4. Plate: ASTM A 167, Type 316.
5. Sheet, Strip, Plate, and Flat Bar: ASTM A 666, Type **316**.
6. Bars and Shapes: ASTM A 276, Type **316**.

C. Trim Members: Provide glazing beads, weatherstrip retainers, flashings, and similar items not functioning as prime structural members.

D. Fasteners: Provide stainless steel fasteners warranted by the manufacturer to be non-corrosive and compatible with steel members, trim, hardware, anchors, and components of connected work.

1. Provide all exposed fasteners with vandal and tamper-proof heads.
2. Drill and tap for all fasteners in steel shapes prior to finishing. Fasteners shall not protrude through steel flange.

4. Anchors, Clips, and Window Accessories: Fabricate units of stainless steel or hot-dip zinc coated steel.

C. Doors Hardware: Specified under Section 08710, FINISH HARDWARE.

D. Sloped Glazing Cap System: Provide custom glazing angles in custom aluminum extrusions matching profiles indicated, curved to match curvature of bent glass system. Clad aluminum extrusions with lead-coated copper sheet in conformance with Section 07600, FLASHING AND SHEET METAL WORK. Protect aluminum extrusions from galvanic action.

1. Provide custom lead-coated copper crimped-on covers in profiles and dimensions indicated.

2. Provide cap-bead sealant after crimped-on cap has been installed. Refer to Section 08800, Glass and Glazing for cap sealant.

3. Coordinate all work of this Section with rafter system specified as work of Section 05100 Structural Steel.

E. Glass and Glazing: Provide glass and glazing conforming to requirements specified under Section 08800, GLAZING.

2.02 FABRICATION

A. Fabricate entrances, glass wall systems, and bent glass glazed roof systems to match profiles and dimensions indicated. Provide work to sizes, shapes, and profiles indicated on approved shop drawings. Make work with uniform, tight joints. Provide units that are reglazable without dismantling.

B. Glaze entrances, wall systems, canopies and bent glass glazed roof using glass and glazing materials complying with Section 08800, GLAZING.

C. Provide subframes, sills, mullions and cover plates as needed for a complete weatherproof assembly.

2.03 FINISHES

A. Stainless Steel Finish: Provide stainless steel finishes as listed below.

1. Stainless Steel Finish: AISI Finish No. 4.

PART 3 - EXECUTION

3.01 INSPECTION

A. The Installer/Erector shall examine substrates, supports, and conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning of installation will be construed as Installer/Erector accepting substrates and conditions.

3.02 INSTALLATION

A. General Installation Requirements: Strictly comply with manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this section.

B. Installation: Install units plumb, level, in alignment and plane without warp or rack. Anchor securely in place.

C. Dissimilar Materials: Isolate all dissimilar materials.

D. Sealants: Install sills and subframes in a thick bed of sealant. Provide sealant at all joints and intersections and at all perimeters. Comply with applicable requirements of Section 07920, Sealants and Caulking.

E. Flashing: Coordinate with flashing installation to ensure weathertight construction and assembly. Thoroughly seal all penetrations through flashings with thick bed of sealant. Comply with applicable requirements of Section 07600, FLASHING AND SHEET METAL WORK.

F. Glass and Glazing: Comply with applicable requirements of Section 08800, GLAZING.

3.03 TOLERANCES

A. The following allowable installed tolerances are allowable variations from locations and dimensions indicated by the Contract Documents. Do not add these tolerances to any allowable tolerances indicated for other work.

1. Allowable Variation from True Plumb: $\pm$ 1/8 in. in 20 ft.-0 in.
2. Allowable Variation from True Line: $\pm$ 1/8 in. in 20 ft.-0 in.
3. Allowable Variation from True Level: $\pm$ 1/8 in. in 20 ft.-0 in.

3.04 CLEANING, TOUCH-UP, AND PROTECTION

A. Clean exposed surfaces using manufacturer recommended materials and methods. Remove and replace work which cannot be successfully cleaned.

B. Touch-up damaged coatings and finishes. Eliminate all visible evidence of repair.

C. Provide temporary protection at all times during the course of the work, and immediately after completion to ensure the work of this Section is not damaged or deteriorated in any way at time of final acceptance. Remove temporary protections and reclean as necessary immediately prior to final acceptance.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM NO.	DESCRIPTION	UNIT
0830.550	Glazed Enclosures & Entrances	Lump Sum

END OF SECTION

SECTION 09100

METAL SUPPORT SYSTEMS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing and installing metal support systems for the support of gypsum drywall, and cement plaster systems, as specified in Standard Specifications Construction Section 09100, except as modified herein.

1.02 QUALITY CONTROL

C. Fire-Resistance Ratings: Where indicated, provide materials and construction which are identical to those of assemblies whose fire resistance rating has been determined per ASTM E 119 by a testing and inspecting organization acceptable to authorities having jurisdiction.

1. Provide fire-resistance-rated assemblies as indicated on Drawings, identical to those indicated by reference to GA File Nos. in GA-600 "Fire Resistance Design Manual" or to design designations in U.L. "Fire Resistance Directory" or in listing of other testing and agencies acceptable to authorities having jurisdiction.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL No separate measurement or payment will be made for work required under this Section. All costs in connection therewith will be considered incidental to the item of work to which they pertain.

-END OF SECTION-

SECTION 09210

SPRAY APPLIED ACOUSTICAL CEMENT PLASTER

PART 1 – GENERAL

DESCRIPTION

1.01 WORK INCLUDED:

A. This section specifies furnishing and installing sprayed on decorative/acoustical insulation as indicated on drawings.

1.02 QUALITY ASSURANCE:

A. Provide testing results and procedures which have been certified by an accredited independent testing laboratories. Thickness of test samples must be determined and reported by acoustical laboratory.

1. NRC not less than 0.75 at 1-5/8 inch thickness and coefficient not less than 0.74 at 500 Hz. Conduct testing on solid backing with no air gap.

B. Installer: licensed by manufacturer.

C. Control Sample: Prior to installation of final coat, apply an area of 50 sq. ft. in presence of architect, for approval of finish texture, as selected from samples.

1.03 SUBMITTALS

A. Submit manufacturer's installation instructions, test data substantiating compliance with quality assurance.

B. Submit 12 inch square sample of sprayed on insulation showing texture variations for approval. Resubmit as required until approved. All samples must be certified by manufacturer that they are representative of the texture which was acoustically tested in supporting acoustical test reports.

C. Submit test reports from all suppliers showing material to be 100% free of asbestos, mineral fiber, polystyrene and cellulose.

D. Submit certification of applicator licensing.

E. Submit acoustical test data for specified finish.

1.04 MATERIAL HANDLING

A. Keep material dry until ready for use.

1.05 WARRANTY

A. Manufacturer shall warrant the material to be supplied, agreeing to repair/replace that which has cracked, flaked, dusted excessively, peeled or fallen from substrate, or otherwise deteriorated to a condition where it would not perform effectively as a intended for a sound absorbent purpose; due to defective materials and not due to abuse, improper maintenance, unforeseeable ambient exposures, or other causes beyond anticipated conditions by manufacturer. The warranty period will be 10 years from date of substantial completion.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Materials shall be Acoustement 40 manufactured by Pyrok, Inc., Mamaroneck, N.Y. (914) 777-7070,
SoundSorb manufactured by Concrete Solutions, Inc. (CSI), Austin, Texas, 512.327.8481; K-13 Spray-On, International Cellulose Corporation., Houston, TX 77245-0006, (713) 433-6701; or equal.

B. Color shall be Gray or selected by the architect or engineer.

C. Texture shall be standard texture.

PART 3 - EXECUTION

3.01 INSPECTION AND PREPARATION

A. Examine all substrate and conditions.

B. Assure substrate is free of oil, grease, dirt, paint, or other matter which would impair bond or install metal lath as recommended by the manufacturer.

C. Do not proceed until said substrate and conditions are acceptable.

D. Prepare substrate by filling voids and cracks and offsets, remove projections that result in telegraphing presence of imperfections.

E. Prime substrate with primer or bonding agent as recommended by the manufacturer.

F. Do not apply insulation material when temperature is below 44 degrees F (ambient), or substrate is below 40 degrees F.

G. Mask all adjoining surfaces in order to minimize damage from overspray.

H. Provide ventilation if required, and avoid excess drying rates.

I. Provide tarps or temporary enclosures as necessary to confine operations.

J. Perform all patching and repairing of insulations required to be done due to cutting, etc., by other trades.

3.02 APPLICATION

A. Apply in accordance with manufacturers printed instructions using any rotary stator plastering pump or other spray equipment approved by the manufacturer.

B. Install to thickness indicated or thickness required to achieve NRC specified.

C. Ensure that texture and color are all as per control sample.

3.03 CLEANING AND PATCHING

A. Remove overspray and fall out material immediately upon completion of the work in each area. Clean surfaces to remove evidence of soiling. Repair or replace damaged work surfaced to acceptable conditions.

B. Coordinate work with other work, to minimize possibility of damage to insulation resulting from performance of subsequent work. As other units of work are completed in each area, patch damaged areas or surfaces of insulation by over spraying to match original installations, or by patching procedures as required to provide acceptable results.

PART 4 – MEASUREMENT AND PAYMENT

4.03 PAYMENT ITEMS

Item No.	Description	Unit
Item 0950.011	Acoustical Treatment	SF

SECTION 09220

CEMENT PLASTER

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies cement plaster, in accordance with Standard Specifications Section 09220, except as modified herein.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Cement

1. Portland cement shall conform to ASTM C 150 Type I or II.

E. Acrylic-Based Finish Coat: Factory-mixed formulation of acrylic emulsion, colorfast mineral pigments, and fine aggregates specifically recommended by acrylic-based finish manufacturer for use over Portland cement plaster base coats.

1. Provide acrylic-based finish coats as manufactured by Parex Incorporated, Sto Industries, Thoro System Products, or equal as approved by the Engineer.

2. Color shall be as selected by Engineer from manufacturer's standard choices.

PART 3 - EXECUTION

3.06 PLASTER SYSTEMS SCHEDULE

A. Interior

1. Provide System A for all exposed-to-view plaster work, with acrylic based, integrally colored finish coat.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM NO.	DECRIPTION	UNIT
0910.000	Lath and Plaster	Lump Sum

-END OF SECTION-

SECTION 09250

GYPSUM WALLBOARD

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing and installing gypsum wallboard systems, as specified in Standard Specifications Construction Section 09250, except as modified herein.

1.06 JOB CONDITIONS

C. Fire-Resistance Ratings: Where indicated, provide materials and construction which are identical to those of assemblies whose fire resistance rating has been determined per ASTM E 119 by a testing and inspecting organization acceptable to authorities having jurisdiction.

1. Provide fire-resistance-rated assemblies as indicated on Drawings, identical to those indicated by reference to GA File Nos. in GA-600 "Fire Resistance Design Manual" or to design designations in U.L. "Fire Resistance Directory" or in listing of other testing and agencies acceptable to authorities having jurisdiction.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM NO.	DESCRIPTION	UNIT
0926.000	Gypsum Drywall Systems	Lump Sum

- END OF SECTION -

SECTION 09300

TILE

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing and installing tile in accordance with Standard Specifications Section 09300, except as modified herein.

1.03 QUALITY CONTROL

D. Reference Standards

1. American National Standards Institute (ANSI):

   a. A108.5 Installation of Ceramic Tile with Dry-Set Portland Cement Mortar or Latex-Portland Cement Mortar.
   b. A118.4 Latex-Portland Cement Mortar Specifications
   c. A118.8 Modified Epoxy Emulsion Mortar/Grout

2. American Society for Testing and Materials (ASTM):

   a. C 144 Aggregate for Masonry Mortar
   b. C 150 Portland Cement
   c. C 206 Finishing Hydrated Lime
   d. C 207 Hydrated Lime for Masonry Purposes

E. For each type of tile required for the work of this Section, provide products of one manufacturer. Provide mortar, grout and adhesive materials that are acceptable to the tile manufacturers.

F. Mock-Up: Prior to commencing work of this Section, provide minimum 4 ft. x 4 ft. mock-ups of each type of tile work and installation required under the Contract, at locations acceptable to the Engineer. Obtain Engineer's acceptance of visual qualities and construction techniques. Protect and maintain acceptable mock-up throughout the work of this Section to serve as criteria for acceptance of this work. Approved mock-ups may be incorporated into the finish work.

G. Other specification sections that directly relate to the work of this Section include, but are not limited to, the following:

1. Section 03300 – Cast-In-Place-Concrete.
2. Section 04200 – Unit Masonry.
3. Section 09220 – Cement Plaster

1.04 SUBMITTALS

E. Samples
1. Initial Selection Samples: Submit manufacturer's stock samples of wall and floor tile of the types specified, including full range of standard colors for selection by Engineer.
2. Verification Samples: Submit duplicate grouted panel for each selected color and type. Panels shall be minimum 24 in. x 36 in.

1.06 JOB CONDITIONS

A. Environmental Conditions

2. Perform work only when conditions are within the limits established by manufacturers of the materials and products used. Comply with minimum temperature recommendations of manufacturers for bonding and grouting materials in other than Portland cement mortar. Maintain manufacturer's recommended curing/setting temperatures for a period of at least 7 days after installation.

B. Substrates: Proceed with work only when substrate construction and penetrating work is complete.

C. Ventilation: Comply with manufacturer's requirements and recommendations.

PART 2 - PRODUCTS

2.01 MATERIALS

B. Tile Types

1. Unglazed Tile:

a. Type A, Ceramic Mosaic Floor Tile at Toilet Rooms:

1) Type: Cushion-edge, impervious porcelain tile, in solid or mottled color(s) as selected by Engineer. Ceramic mosaic tile shall be as manufactured by American-Olean Tile Company; Dal-Tile Corporation; Dallas Ceramics, United States Ceramic Tile Company; Wenczel Tile Company; or equal approved by Engineer
2) Floor tile shall be 2 in. x 2 in. x 1/4 in. nominal thickness, ceramic mosaics premounted on sheets, with slip resistant finish.
3) Ceramic base shall be ceramic mosaic cove tile to match floor tile in colors and shapes required, 2 in. x 2 in..

c. Type C, Paver Tile:

1) Type: Unglazed porcelain, natural clay formed by the dust-pressed, hand made, or extruded method, and equal to 12 in. by 12 in. by 5/8 in. Avisco Fiandre porcelain tile; Summitville Tile porcelain tile; Crossville Tile porcelain tile; or approved equal; conforming to ANSI A 137.1; or equal approved by Engineer

2. Glazed Tile:

a. Type A, Wall Tile:

1) Type: Cushion-edge, impervious porcelain tile, in solid or mottled color(s) as selected by Engineer. Ceramic mosaic tile shall be as manufactured by American-Olean Tile Company; Dal-Tile Corporation; Dallas Ceramics, United States Ceramic Tile Company; Wenczel Tile Company; or equal approved by Engineer

2) Size: As follows:

a) Toilet Room Wall Tile: Wall tile shall be 4 in. x 4 in. x 1/4 in. nominal thickness, ceramic mosaics premounted on sheets.

3) Face: Plain.

4) Backs: Manufacturer's standard raised or depression pattern.

5) Glaze: High Gloss.

6) Color: As selected by Engineer.

E. Joint Materials: Provide stainless, highly chemical resistant epoxy grout for ceramic tile, pavers and stone. Epoxy grout shall be resistant to urine, acids and alkalis, petroleum distillates, oil solvents and food wastes and shall meet or exceed the following requirements:

Test	Test Method	Value
Density		108 lbs/cubic foot
Compressive Strength	ASTM C109, Modified	>6,600 psi
Shear Bond Strength	ANSI A118.	>1000 psi
Water Absorption	ANSI A118.4	<1/2%
Hardness	ASTM D2240	D70
Water Cleanability	ANSI A118.3	45 min.
Workability	at 72°F	1 hour
Installation Temp. Range	50 °F to 90°F	
Service Temp. Range	230°F	
Time to Traffic	at 70°F	Normal 24 hours

PART 3 - EXECUTION

3.03 INSTALLATION

A. General Requirements

6. Layout tile so that during installation, no cut tile is less than 1/2 its original dimension.

B. Interior Systems

3. Wall tile shall be installed using Installation Method C.

5. Cement Mortar Bed over Concrete Subfloor: TCA F114, Latex modified Portland cement mortar, bond coat and epoxy grout. Provide cleavage membrane and wire mesh reinforcing in compliance with TCA Handbook.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM NO.	DESCRIPTION	UNIT
0930.000	Tile Work	Lump Sum

-END OF SECTION-

SECTION 09360

MODULAR TACTILE SURFACES

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing and installing of modular tactile surface tile at station platforms.

B. Related Work Specified Elsewhere::

1. Section 03300 - Cast-in-Place Concrete
2. Section 07920 - Sealants and caulking

1.02 QUALITY ASSURANCE

A. Manufacturer: Tile must be manufactured by a company specializing in the manufacture of modular tactile surface tiles as used in transit systems for guidance of the sight impaired. Product must have been installed at other locations with successful records of performance.

B. Installer: The Installer must be a manufacture or manufacturer-approved installer with documented experience in work similar to that of this Section. The Installer must be approved by the Engineer before installation of the tile may begin.

C. Warranty: In addition to the requirements of the General Conditions, furnish a warranty jointly executed by the tile manufacturer and the installer. Warrant the work executed in this Section for a period of five years against failure of tile material, workmanship, and installation for the work performed under the supervision of the manufacturer of the tile. The Warranty shall include breakage, deformation, fading, chalking of finishes, loosening of tiles, and mechanical fasteners, which are used for securing the tiles to the platform.

D. For first time installers and suppliers of tactile tile to the MBTA, a meeting with representatives of the Engineer, Contractor, Surface Preparation subcontractor, Manufacturer, and Installer in attendance is mandatory. The agenda shall include the review and clarification of the specification, installation procedures, quality control, inspection and acceptance criteria and installation schedules. In no case will installation be allowed to commence until this meeting is held.

E. Mock-ups:

1. After approval of materials, erect a mock-up at the work site where directed as follows:

a. Install an eight-foot-long tile mock-up, using all specified materials.

2. Assign the same construction crew to both the mock-up and the permanent work.

3. If not approved, remove and replace mock-up at no additional cost to the Authority. Repeat procedure until approval is granted.

4. Approved mock-up shall serve as the quality standard for appearance, tolerances, and workmanship.

5. Approved mock-up may be incorporated in the permanent work, with the following certification

   a. Manufacturer's certification that all products meet specified requirements, as verified by independent testing agency.

   b. Manufacturer's approval of installer, if other than manufacturer, and detailed work history with the product proposed for installation.

6. Protect and maintain approved mock-up in accepted condition throughout the construction period. When no longer required, remove and dispose of off site, if not incorporated into the permanent work.

F. Some items in this Section, or the installation thereof, shall comply with the *Americans with Disabilities Accessibility Guideline for Buildings and Facilities* (ADAAG) and/or the *Rules and Regulations of the Massachusetts Architectural Access Board, 521 CMR* (AAB Regs). In case of conflict between regulations giving greater access shall prevail.

1.03 SUBMITTALS

A. Shop Drawings: Show complete layout and fabrication details, composite structure, dimensions of tiled areas, and affected adjacent areas. Provide large scale plan details of the tiles at the curves, including fastener locations.

B. Product Data: Manufacturer's catalog cuts, material specifications, installation and maintenance instructions, and other data pertinent to the work of this Section.

1. Samples: One full-size sample of the type, size, pattern, and color of tile required, and five 6" x 6" samples for records.

2. Certification:

   a. Manufacturer's certification that all products meet specified requirements, as verified by independent testing agency.

   b. Manufacturer's approval of installer if other than manufacturer, and detailed work history with the product proposed for installation.

3. Support Stock: After completion of the work, furnish a minimum of five percent of the total amount of tile furnished, from the same manufactured lot as materials furnished for work of this Section, in sealed, protective packaging marked with Contract number, lot number and identification contents.

C. Certification: Provide manufacturer's certification that all materials meet specified requirements, as verified by an independent testing agency. Include certification that the installer is approved by the manufacturer of tiles.

D. Submit certified test reports for all tests shown in Article 2.02 B, indicating for each test whether or not the tile passes or fails the passing criteria. Test report shall be current and shall not predate he notice to proceed date of this contract by more than two years.

E. Submit record of past installations with contact references.

1.04 DELIVERY, STORAGE AND HANDLING

A. Deliver materials and products in unopened, factory labeled packages. Store and handle in strict compliance with manufacturer's instructions and recommendations. Store under cover and protect from all damage and pilferage

PART 2 - PRODUCTS

2.01 GENERAL

A. The modular tactile tile surface system shall differ from adjoining surfaces in resiliency or sound-on-cane contact as set forth by the latest requirements of the Americans with Disabilities (ADA) and the Massachusetts Architectural Access Board (AAB). Such reference is intended to establish quality and performance characteristics and meet the legal definition of the law.

2.02 MODULAR TACTILE SURFACE TILE

A. Provide platform edge surfaces with 24 in. x 48 in. sheets, as indicated on Drawings. Provide 1/8 in. minimum to 3/16 in. maximum thicknesses of the non-domed surface. The tactile tile shall be fabricated with a solid dome and solid body. Tile shall have a truncated dome design in patterns conforming to Americans with Disabilities Act Architectural Guidelines (ADAAG) requirements. Tiles shall have integral safety yellow color throughout the entire thickness of material.

B. Tiles must be chemically test certified to resist corrosion and color change and be resistant to ultraviolet rays. Tiles shall exhibit the following properties, and be tested using the corresponding test method, and meet the respective passing criteria, as follows:

a. **Property:** Water Absorption

Test Method: ASTM D570-95- Standard Test Method for Water Absorption of Plastics

Passing Criteria: No greater absorption than 0.35% of weight increase due to saturation.

b.	**Property**:	Compressive Strength
	Test Method:	ASTM D 695-96 - Standard Test Method for Compressive Properties of Rigid Plastics
	Passing Criteria:	13,000 psi average compressive strength.
c.	**Property:**	Slip Resistance
	Test Method:	ASTM C1028-96 - Standard Test Method for Determining the Static Coefficient of Friction of Ceramic Tile and Other Like Surfaces by the Horizontal Dynamometer Pull-Meter Method.
	Passing Criteria:	Minimum coefficient of friction of 0.80 with Neolite under wet and dry conditions.
d.	**Property:**	Impact Resistance
	Test Method:	ASTM D 5420-96 - Standard Test Method for Impact Resistance of Flat, Rigid Plastic Specimen by Means of a Striker Impacted by a Falling eight Gardner Impact).
	Passing Criteria:	No cracks at ambient temperature.
e.	**Property:**	Accelerated Weathering
	Test Method:	ASTM G 26-96 - Standard Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials.
	Passing Criteria:	No deterioration, fading, or chalking of tile surface after 2,000 hrs. of exposure.
f.	**Property:**	Fire Resistance
	Test Method:	ASTM E 136-96a - Standard Method for Behavior of Materials in a Vertical Tube Furnace at 750°C
	Passing Criteria:	Material shall conform to the contained criteria to be considered noncombustible.
g.	**Property:**	Flexural Strength
	Test Method:	ASTM D 790-96a - Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.
	Passing Criteria:	15,000 psi average flexural strength.

h. **Property:** Stain and chemical resistance

Test Method: ASTM D 543-95 - Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents.

Passing Criteria: No staining or dissolution of the material.

D. Modular tactile surface tile will not be cast integrally with platform concrete units but are to be mechanically fastened as per Article 2.03 of this specification section.

2.03 FASTENING SYSTEM

A. The fastener system shall consist of stainless steel screws anchored into plastic sleeves placed into predrilled holes in the existing concrete platform, meeting the following requirements:

1. Sleeve: Plastic sleeve shall be corrosion resistant and temperature resistant from -40° F to +104° F. The sleeves shall be installed in pre-drilled holes sized to the sleeve manufacturer's recommendation.

2. Screws: Supply stainless steel screws, oval head tamperproof, 1/4 in. diameter by 1-3/4 in. long, set in a high quality plastic sleeve. The head of the screw shall be powder coating finished to match the color of the tile or covered with a cap to match the tile finish. Screws shall be hammer driven to set into the sleeve and shall be removable with the use of a special tool for the tamperproof head.

3. Number: The number of fasteners used shall be as required to completely fasten the tile to the platform substrate, but in no case will less than 10 fasteners be installed in a 2 ft. by 4 ft. modular unit. Fasteners shall not be installed in the body of the tactile material.

2.04 ADHESIVE

A. Polyurethane single or two-part elastomeric adhesive as manufactured by Mapei, International Coatings (ICO-GEL™), Elastiment™ as manufactured by Boardi Products, or other adhesive as recommended by the Tactile Warning Tile manufacturer.

B. Performance criteria: Tactile Warning Tiles adhered to concrete shall meet or exceed the following tests:

1. Accelerated aging and freeze thaw test of tactile warning tile and adhesive: per ASTM-1037 requirements, shall show no evidence of cracking, delamination, checking, blistering, loosening of the tile, or other defects.

2. Salt and Spray performance of the RTF tactile warning tile adhesive system: per ASTM-B117 requirements, shall show any deterioration or other defects after 100 hours of exposure.

PART 3 - EXECUTION

3.01 GENERAL

A. The work of this Section shall be performed by the manufacturer of the tactile tiles, or a manufacturer and Authority approved installer.

3.02 INSPECTION OF SURFACES

A. Carefully inspect substrates for conditions affecting application and performance of the work of this Section. Report defects in writing to Engineer. Do not proceed with tactile tile installation work until unsatisfactory conditions have been corrected.

B. Beginning work shall constitute acceptance of its conditions and any defects in tactile tile installation work resulting from such accepted surfaces shall be corrected without further expense to the Authority.

3.03 PREPARATION

A. Coordinate tile installation, working with prior and subsequent work of other trades.

B. Ensure that concrete substrate is smooth, clean, cured and trowel finished or scarified, free from curing compounds or surface coatings. The tactile tile shall be installed on poured in place, retractable edge units, or precast concrete units and **not** on leveling compounds or fillers.

C. The platform surface shall be scarified or depressed during forming, except for 2 foot wide platform edge units, and preparation shall depend on the thickness of the modular tile. The surface preparation shall also be as recommended by the manufacturer for installation of that particular product so the body of the tile is to be recessed flush with the finished platform surface so that only the domes project above the top of the finished surface.

D. Any slurry or concrete dust produced by the scarifying procedure and/or drilling for mechanical anchors shall be vacuumed from the platform during the preparation process to prevent the slurry from cementing the ballast or fouling the track drains. This contractor shall provide protection as required to prevent any residue from entering the ballast area.

E. Electrical or signal cables under the platform edges or mounted on the support walls shall be protected, as required, using polyethylene or similar waterproof material.

3.04 TILE INSTALLATION

Install tile as shown on Contract Drawings, approved Shop Drawings, and in accordance with manufacturer's instructions and the following:

A. The tiles shall be dry-fit, approved by the engineer, prior to installation to ensure a first class installation.

B. At the platform radius tiles need to be installed with the platform edge tangent to the radius with the ends trimmed to provide a joint tangent to the curve and square to

adjoining tiles. Any domes cut in the trimming shall be beveled and polished to match the finish of the tile.

C. Apply sealant only at expansion joints in accordance with Section 07920.

D. Fasteners and adhesives, as required by the platform conditions, shall be used to fully fasten the tile to the platform to provide complete contact between the tile and the platform.

3.05 PROTECTION

A. During construction and prior to opening the platform edge for public use, cover all tactile surfaces with an appropriate covering material, temporarily secured in place, to protect it from damage from construction activity. Remove covering when protection is no longer needed and dispose of it off site in a manner conforming to all appropriate laws and regulations.

B. Prohibit all construction vehicle traffic from riding on newly tiled surfaces. Do not place or store construction equipment or tools directly on tiled surfaces.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM	DESCRIPTION	UNIT
0932.307	Platform Tactile Edge	LS

END OF SECTION

SECTION 09821

TWO-COMPONENT POLYMER CEMENTITIOUS PROTECTIVE COATING

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the requirements for furnishing and application of two-component polymer cementitious coating for protection against abrasion, waterproofing and dampproofing with a decorative appearance. Protective Coating is to be used as a floor finish for MCC room and electrical unit substation.

1.02 QUALITY ASSURANCE

A. Applicator Qualifications

1. Installation shall be by an experienced applicator, approved by the manufacturer of the materials supplied.

B. Requirements of Regulatory Agencies

1. Materials and installation thereof shall meet the requirements of all local, state, or federal codes, regulations and ordinances having jurisdiction.

C. Sample Area

1. Contractor shall apply the coating on a sample area not less than 10 sq. feet in size. When approved, the sample area shall serve as a standard of acceptance for all cementitious coating work.

1.03 SUBMITTALS

A. Manufacturer's Descriptive Brochures. Submit manufacturer's literature describing products.

B. Installation Instructions. Submit manufacturer's recommended instructions for application of products.

C. Color Samples. Submit manufacturer's standard range.

D. Certificates of Compliance with properties listed herein below and single source manufacturer for all components.

1.04 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Deliver materials to the site in original packages or container bearing the manufacturer's labels and identification.

B. Store and handle materials to prevent inclusion of foreign matter and water or deteriorating effects of hot and cold temperatures.

1.05 JOB CONDITIONS

A. Environmental Requirements

1. Coating shall be applied only when concrete surface temperature and ambient temperature is 45 degrees F. and rising, preferably between 50-90 degrees F.

B. Protection

1. Cover finished coated surfaces with heavy building paper before foot traffic. Protect surfaces against vehicular and pedestrian traffic during curing period (foot traffic 2-3 hours, pneumatic tires approximately 4 to 6 hours at 73 degrees; longer at lower temperatures).

C. Safety

1. The Contractor shall require applicators to wear protective clothing, gloves, goggles and barrier creams.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Cementitious Protective Coating. The cementitious system shall consist of a factory pre-proportioned, 2-component kit the components of which conform to the following requirements and the resultant cured system exhibits the following properties:

1. Component A shall be a liquid polymer emulsion of an acrylic copolymer base and additives. This acrylic copolymer shall have the following properties:

pH	4.5 - 6.5
Tear Strength	Approx. 990 - 1420 psi
Particle size range	Less than 0.1 micron (ASTM D968)

2. Component B shall be a blend of selected Portland cement, specially graded aggregates, and admixtures to control setting time and workability.

3. Properties of Cured System:

a. Abrasion Resistance	45 liters/mil minimum (ASTM D968)
b. Bond Strength (Pull-off Method)	100% concrete substrate failure

c. The system shall not produce a vapor barrier.

d. The system shall be thermally compatible with concrete.

e. Conforms to ECA/USPHS Standards for surface contact with potable water.

B. Non-Slip Aggregate.

1. Aggregate shall be Ottawa silica sand, or an approved equivalent. The sand shall be so graded that 100% by weight passes a No. 30 sieve, 20 to 30 percent passes a No. 50 sieve and 0 to 5 percent passes a No. 100 sieve.

2. Sand shall be furnished on the project as a pre-dried product in moisture-resistant, polyethylene lined bags.

PART 3 - EXECUTION

3.01 APPLICATION REQUIREMENTS

A. All mixing and application of the cementitious protective coating shall be done in strict accordance with the printed instructions of the approved manufacturer and as directed by the Engineer. The Contractor shall submit to the Engineer, when requested, evidence indicating that the proposed applicators are fully qualified to perform the work and any proposed applicator found to be not qualified shall, at the written request of the Engineer, be removed forthwith by the Contractor.

B. The Engineer shall require that the Contractor demonstrate proven ability and competence in the application of this product, in conformance with the manufacturer's printed instructions.

C. If any part of this work shall be found defective (because of improper preparation of surfaces, mixing of components or application of coating) at any time before the final acceptance of the item, the Contractor shall, at his own expense, make good such defect to the satisfaction of the Engineer.

D. Cementitious protective coating shall be applied to the floor slabs of the Electrical Substation No. 3 and the MCC Room at Shaft G-10.

3.02 PREPARATION OF SURFACES

A. Prior to installation of materials, clean and prepare surfaces by sand blasting to remove all laitance, oil, grease, paint and other bond-inhibiting substances. An accredited representative of material manufacturer shall inspect the sub-strate and report any unsatisfactory conditions to the Engineer. Commencement of work shall constitute material manufacturer's acceptance of substrate for bonding of new material.

B. All surfaces to be coated must be clean and sound. All projections, rough spots, etc. shall be dressed off. The entire surface to be coated shall be waterblasted using a minimum 5000 psi pressure to remove laitance, dirt, or other contaminants and disintegrated materials.

C. A Waterblast Cleaned Surface Finish is defined as one from which all laitance, weak surface concrete or mortar, dirt, and contaminants are removed completely leaving a clean, damp sound

surface to which a polymer-cementitious coating system will strongly adhere. It is further the intent of the blasting operation that it remove the surface of the concrete deep enough to eliminate any formation over voids (also referred to as "bug holes" or "air holes"). The surface of the concrete, after blasting, shall be similar in texture to a medium/coarse sandpaper finish (reference No. 1 grit sandpaper) to provide a mechanical bond for the coating system.

D. When using waterblasting equipment, all work shall be shielded for the protection of the public and comply with all applicable state, federal, or local laws, ordinances, rules, and regulations having jurisdiction regarding environmental concerns.

E. At the direction of the Engineer, the Contractor shall thoroughly clean up and dispose of the debris resulting from this operation.

F. Application of the coating shall not be started until the blasted surfaces have been inspected and approved by the Engineer.

3.03 APPLICATION

A. Mix compound in strict adherence to manufacturers instructions. Mix only amount that can be used in 1´ hours at 63 degrees F.

B. The coating shall be applied on horizontal surfaces with high-quality brushes, rollers or by airless spray at such rates as to provide a final minimum total dry film thickness of 16-20 mils. Ambient and surface temperatures shall be between 50-90% F. Coatings shall be provided with a non-skid surface by means of approved aggregates incorporated in the top coat as recommended by the manufacturer and as follows:

1. Skid-Resistant Surface. The thickness of the final coat shall be a minimum of 12 mils (150 sq. ft. per gallon). While it is still liquid, apply aggregate by dropping vertically into the film at a rate of 1-2 lbs per sq. ft.

3.04 CLEANING

A. At completion of coating work, clean all flooring materials from adjoining work.

3.05 MANUFACTURER"S FIELD REPRESENTATIVE

A. The Contractor shall arrange with the materials manufacturer or distributor to have the services of a competent field representative at the work site prior to any mixing of components to instruct the work crews in the proper mixing and application procedures. He shall remain at the job site after work commences and continue to instruct until he and the Contractor and Engineer are satisfied that the crew has mastered the technique of installing the system successfully. The representative shall make periodic visits to the project as the work progresses and shall confer on each visit with the Contractor and Engineer.

B. The manufacturer's field representative shall be fully qualified to perform the work and shall be subject to the approval of the Engineer.

PART 4 - MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Measurement for two-component cementitious protective coating will be made on a contract unit price basis per square foot complete in place including all surface preparation, all labor, materials, accessories and incidentals as indicated on the drawings and specified herein.

4.02 PAYMENT. Two-component cementitious protective coating will be paid for at the contract unit price for quantities determined as specified above.

ITEM NO.	DESCRIPTION	UNIT
0981.005	TWO-COMPONENT CEMENTITIOUS PROTECTIVE COATING	SF

END OF SECTION

SECTION 09841

SPRAYED FIREPROOFING

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies sprayed-on fireproofing systems, in accordance with Standard Specification Section 09841, except as modified herein.

1.05 RELATED WORK

A. Carefully examine all of the Contract Documents for requirements which affect the work of this section.

B. Other specifications sections which directly relate to the work of this section include, but are not limited to, the following:

1. Section 05100 - Structural Steel

1.06 QUALITY ASSURANCE

A. Installer: A firm which has experience in work of the type required by this section and which is acceptable to the manufacturers of the primary materials.

B. Source: Provide fireproofing materials which are the products of one manufacturer. Provide secondary materials which are acceptable to the fireproofing manufacturer.

1.07 DELIVERY, STORAGE AND HANDLING

A. Deliver materials and products in original unopened factory labeled packages. Store and handle in strict compliance with manufacturer's instructions and recommendations. Protect from all damage. Sequence deliveries to avoid delays, but minimize on-site storage.

1.08 PROJECT CONDITIONS

A. Substrates: Proceed with work only when substrate construction and penetrating work is complete.

1.09 TESTS

A. Fire-Resistance: Provide materials and construction which are identical to assemblies whose fire-resistance rating has been tested in compliance with ASTM E119 by independent agencies acceptable to the Architect and authorities having jurisdiction. Provide systems and assemblies which are fire rated by UL or another recognized testing agency acceptable to authorities having jurisdiction.

B. Burning Characteristics: Provide materials whose surface burning characteristics, when tested in compliance with ASTM E84 are Class A.

C. Field Testing: The Authority may engage an independent testing agency to sample and test completed work for density and thickness in compliance with ASTM E605.

PART 2 - PRODUCTS

2.01 MATERIALS AND PRODUCTS

A. Fireproofing: Provide 41 lb. per cubic foot (air dry density) Portland Cement exfoliated vermiculite product with alkaline resistant fiber reinforcement conforming to the following properties and characteristics:

1. Dry Density: 41 lbs./ft^3 minimum; ASTM E605.
2. Compressive Strength: 800 psi, ASTM C761.
3. Bond Strength: 6800 lbs/ft^2 minimum, ASTM E736.
4. Noise Reduction Coefficient: Minimum 0.60 NRC per ASTM C423 @ 1 in. thickness.
5. Asbestos Content: No asbestos fibers per EPA 400/4M-82-020.
6. Surface Burning Characteristics: 0.0 Flame Spread and 0.0 Smoke Developed per ASTM E84.
7. Air Erosion: Less than 0.025 gm/ft^2 per ASTM E859.
8. Effect of deflection: No effect as per ASTM E759.
9. Effect of Impact: No effect as per ASTM E760.

B. Primers: Provide primers recommended by fireproofing treatment manufacturer which are compatible with steel shop primer [if any].

C. Adhesives: Provide as recommended by fireproofing treatment manufacturer and which comply with applicable fire endurance tests and ratings.

D. Metal Lath: Metal lath shall be galvanized steel, 3.4 lb. diamond mesh conforming to ASTM C 847.

PART 3 - EXECUTION

3.01 INSPECTION

A. New Work: The Installer shall examine substrates and conditions under which this work is to be performed and notify Contractor, in writing, of conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning work means Installer accepts substrates and conditions.

B. Repair of Existing: Inspect existing uncovered fireproofing and identify areas needing repair, patching, or replacement, as directed by Engineer.

3.02 PREPARATION

A. Strictly comply with manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this section.

B. Clean substrates of all substances, primers, or mill scale which might be incompatible or inhibit bond.

C. Prime surfaces if recommended by fireproofing manufacturer.

D. Mask and protect adjacent work which could be damaged by overspray or fallout. Provide temporary enclosures to control conditions and protect the environment.

3.03 INSTALLATION

A. General Requirements: Strictly comply with manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this section. Install fireproofing systems as required to achieve fire-resistance ratings indicated and required by authorities having jurisdiction; match UL designs.

B. Adhesives, Reinforcement, and Metal Lath: Apply adhesive as recommended by fireproofing manufacturer. Provide reinforcement and/or metal lath where movement is anticipated and at locations recommended by fireproofing manufacturer.

C. Thickness and Application: Provide thickness required to obtain fire-resistance ratings required. Provide multiple coats with no one coat exceeding 3/4 in. thickness.

D. Curing: Cure fireproofing in compliance with manufacturer's instructions and recommendations to prevent premature drying.

E. Repair of Existing: Where existing fireproofing systems require repair, prepare areas as necessary to receive new work. Cut out damaged or loose fireproofing material back to solid areas. Provide primers as necessary. Apply new fireproofing in patches as required to provide required fire-resistance performance.

3.04 CLEANING AND PROTECTION

A. Clean non-fireproofed exposed surfaces of all overspray and fallout using materials and methods recommended by manufacturer. Remove and replace work that cannot be successfully cleaned.

B. Provide temporary protection to ensure work being without damage or deterioration at time of final acceptance. Inspect fireproofing immediately before concealing and repair or replace all damaged work.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM NO.	DESCRIPTION	UNIT
0720.105	Fireproofing	Lump Sum

- END OF SECTION -

SECTION 09861

GRAFFITI CONTROL

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies providing graffiti control on exposed surfaces of materials as scheduled.

1.02 QUALITY CONTROL

A. Applicator: Applicator shall be certified in writing as an approved applicator by the manufacturer of the materials to be used.

B. Materials and application thereof shall meet the public health, safety, and environmental requirements of all local, state, or federal codes, regulations, and ordinances having jurisdiction.

C. Source: For each material type required for work of this Section, provide primary materials that are products of one manufacturer. Provide secondary or accessory materials that are acceptable to manufacturers of primary materials.

D. Provide materials that comply with all Federal and State requirements for Volatile Organic Compound (VOC) content.

1.03 SUBMITTALS

A. Product Data: Submit manufacturer's printed product data, specifications, application instructions, use limitations and recommendations for each material used. Provide certifications that materials and systems comply with specified requirements.

B. Submit evidence the product has been successfully tested for anti-graffiti paint protection with the paint having aged on the surface a minimum of three months prior to stripping. Verify that the test procedures were as directed and observed by the Engineer.

C. Test Reports: Provide certified reports for all specified tests.

1.04 PROJECT CONDITIONS

A. Weather: Perform work of this Section only when existing or forecasted weather conditions are within the limits established by manufacturers of the materials and products used.

1. Materials shall be applied only when substrate surface temperature and ambient temperature is 50°F., and rising. Keep materials stored between 65°F. and 85°F. during application. Do not apply to substrate if materials exceed 85°F. in temperature.

2. Avoid wind drift to adjacent surfaces.

3. Divert and protect pedestrian and auto traffic adjacent to application. Remove spills and overspray immediately.

B. Substrates: Proceed with work only when substrate construction and penetration work is complete.

C. Safety: Take all precautions for applicators recommended by product manufacturer.

1. Refer to manufacturer's product literature for complete cautionary and emergency data. Do not use near fire or extreme heat and provide proper ventilation. Applicators shall wear NIOSH/MSHA approved respirators, eye protection, and protective clothing so as to avoid splash to skin and eyes. Read material safety data sheets for additional safety information.

1.05 DELIVERY, STORAGE AND HANDLING

A. Deliver materials and products in unopened, factory labeled packages. Store and handle in strict compliance with manufacturer's instructions and recommendations. Store under cover and protect from weather damage.

B. Sequence deliveries to avoid delays, but minimize on-site storage.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Clear, Anti-Graffiti Sacrificial Coating: Provide as follows:

1. At Porous and Textured Surfaces: At porous and textured surfaces such as concrete, CMU, stone, etc., provide products that meet the following specifications:

a. Form: Water-thin for spray application; white, semi-opaque liquid;
b. Specific Gravity: 0.976;
c. Weight per Gallon: 8.12 lbs.
d. Viscosity at 77°F.: 300 cps;
e. Flash Point: >200°F.
f. VOC: 0g/l.

2. At Smooth, Dense Surfaces: At smooth, dense surfaces such as metal, fiberglass, etc., provide products that meet the following specifications:

a. Form: Thickened white Thixotropic liquid for roller or brush application;
b. Specific Gravity: 0.977;
c. Weight per Gallon: 8.13 lbs.
d. Viscosity at 77°F.: 300 cps;
e. Flash Point: >200°F.
f. VOC: 0g/l

PART 3 - EXECUTION

3.01 INSPECTION

A. Examine substrates, and conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected.

3.02 APPLICATION

A. General Application Requirements: Strictly comply with manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this Section.

B. Protection: Protect adjacent non-coated surfaces from coming in contact with solutions by using a strippable masking agent, plastic sheeting and waterproof tape, or another effective isolator approved by the Engineer and penetrating sealer manufacturer.

C. Surface Preparation: All caulking, patching, and joint sealants shall be installed prior to application of penetrating sacrificial coating. Masonry surfaces shall be cleaned free of dust, surface dirt, efflorescence, contaminants, and membrane curing compounds.

1. New work normally does not require cleaning; however, areas that have become heavily contaminated with surface dirt, oil, etc., during construction, shall require thorough cleaning for best performance of the sacrificial coating. Masonry surfaces shall be power washed with high pressure water and appropriate chemical cleaners to remove contaminants that may have built up. Surfaces to be treated shall be dry and absorbent to assure good penetration of the sacrificial coating.

D. Test Application: Prior to beginning primary work of this Section, provide test application mock-ups for each type of substrate material and condition to be coated at locations acceptable to Engineer and obtain Engineer's acceptance. Protect and maintain acceptable mock-ups throughout the work of this Section to serve as criteria for acceptance of this work.

1. Provide sacrificial coating test mock-ups prior to beginning exterior production graffiti-proofing. Test various techniques and solutions to determine the best methods for the conditions encountered. Provide one 25 s.f. test application for each different method tested and for each different material that has to be graffiti-proofed. Demonstrate Contractor's quality control system to ensure uniform final appearance. Test adjacent non-graffiti-proofed surfaces for possible adverse reactions to graffiti-proofing methods. Use all tested products in strict compliance with the manufacturer's instructions and recommendations. Keep accurate, detailed records of concentrations, solutions, and techniques used to assist in replicating satisfactory results.

E. Application: Penetrating graffiti-proofing shall be applied as packaged; do not dilute or alter material unless otherwise approved by manufacturer. Follow manufacturer's strict recommendations and instructions for different substrates, and for coverage rates.

3.03 FIELD QUALITY CONTROL

A. The Contractor shall establish and maintain throughout the work of this Section an effective quality control program to ensure that work is performed as required by the Contract Documents. Establish specific procedures to prevent chemical damage of adjacent surfaces.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM NO.	DESCRIPTION	UNIT
0986.100	Anti-Graffitti Coating	Lump Sum

-END OF SECTION-

SECTION 09900

PAINTING

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies requirements for furnishing and application of field-applied paint in accordance with Standard Specifications Construction Section 09900, except as modified herein. Work of this Section includes painting of the following:

1. CMU Walls (except polished face CMU);
2. New and existing concrete walls and ceilings;
3. Metal doors and frames;
4. Metal deck;
5. Gypsum wallboard.

C. Work not included in this Section:

1. Shop coats of structural steel, miscellaneous metal, and ornamental metal are specified under their respective sections.

2. Stainless steel, bronze, aluminum, chromium-plate, nickel, lead-coated copper, will not be painted unless otherwise indicated.

3. All other items with factory finish, such as heating grilles and covers, access panels, etc., shall be painted with adjacent work as part of the work of this Section.

D. Provide painting and finishing work throughout exterior and interior of Project as indicated and scheduled on the Drawings and as specified and scheduled herein.

E. Examine Contract Documents in order to determine full extent of painting and finishing work required. Materials provided under other Sections that need painting or finishing and are left unfinished under requirements of other Specification Sections, shall be painted and finished to completion under work of this Section, unless specifically scheduled herein to be left unfinished.

F. Preparatory work of materials and surfaces to receive paint beyond that specified to be done as work of other Sections, shall be included as work of this Section.

1.03 QUALITY CONTROL

F. Source: Provide primers and undercoat paint produced by same manufacturer of finish coats for each substrate.

G. Coordination: Review other Specification Sections where primers are provided to ensure compatibility with finish coatings provided under this Section.

1.04 SUBMITTALS

A. Color selection will be by Method 'A'.

E. Verification Samples: After initial selection of colors, submit representative samples of each paint system color that is to be exposed in the completed work. Show full color ranges and finish variations expected. Provide texture to simulate actual conditions. Define each separate coat, including block fillers and primers. Resubmit samples until required sheen, color, and texture have been approved. Provide samples as follows:

1. Paint Samples for Smooth Surfaces: Provide samples of painted finishes on gypsum drywall or Masonite board having minimum size of 144 sq. in.

2. Paint Samples for Concrete Masonry Units: Provide samples of painted finishes on actual concrete masonry units having minimum size of 4 in. x 8 in.

F. For painting of Structural Steel, submit documentation of minimum slippage coefficient for all paints, and for composite 3-coat system.

1.06 JOB CONDITIONS

C. Scheduling

5. Shop apply intermediate paint coat on Structural Steel to all surfaces that will be permanently covered at the time of field painting (i.e. top flanges platform and canopy of beams and trusses, bottoms of bearing plates, large faying surfaces, etc.). Indicate locations of shop coatings on steel shop drawings.

PART 2 - PRODUCTS

2.01 GENERAL

D. Latex and Alkyd Based Paints and Stains: Provide products of one of the following manufacturers or Engineer approved equal:

1. Benjamin Moore and Co. (Moore).
2. Devoe and Raynolds Co. (Devoe).
3. The Glidden Co. (Glidden).
4. Pratt and Lambert (P & L).

E. High Performance Paint Coatings: Provide products of one of the following manufacturers or Engineer approved equal:

1. DuPont.
2. Tnemec Company, Inc. (Tnemec).
3. International Protective Coatings (IPC).
4. Ameron.

F. Signage Paint: For signage and graphics painted on door surfaces, provide Mathews Acrylic Polyurethane, by Mathews Paint Company, Wheeling, IL 60090, or Engineer approved equal as manufactured by Devoe and Raynolds Co.; or Pratt and Lambert.

G. Materials used shall be best grade products of their respective kinds. The Painting Schedule is based on products of the above named manufacturers. These are specified to establish a standard of quality and kind of material desired. Provide these products, or equals as approved by the Engineer.

H. Note: If substitutes are proposed, submit complete schedule showing materials specified and equivalent materials proposed as substitutes. Provide complete manufacturer's product data on proposed materials. Substitutes must be approved by Engineer before commitment for materials is made.

I. Assume full responsibility for proper performance of materials, for method of application, and for compatibility of materials applied over shop coats or other coats previously applied, including but limited to primers, sealers, preservative treatments, etc. Notwithstanding specific schedules in this Section, select primers which have been verified to be appropriate for each of the substrates and finishes encountered.

J. Provide miscellaneous painting materials such as linseed oil, shellac, turpentine, and thinner of the highest quality.

K. All paints and finishes for Structural Steel shall be manufactured by TNEMEC, DuPont, Hempel, Rustoleum, or Engineer approved equal.

L. Structural Steel shop primer paint system shall qualify as a "Class A or B Coating System" with a slip coefficient of 0.33 or 0.50 respectively, as determined by "Testing Method to Determine Slip Coefficient for Coatings Used in Bolting Joints", Specification for Structural Joints using ASTM A325 or ASTM A490 Bolts, R.C.S.C., November 13, 1985, as referenced in AREA Chapter 15.

2.03 MATERIALS

A. High Performance Coatings - General: Tnemec products and materials are specified in the following table in order to establish the level of quality and performance required. Products by Ameron, IPC or DuPont, or equal will be considered if submitted for approval, provided that they meet the quality and performance level established by the products listed. Provide materials identified and specified in the following table and as required for systems specified in paragraph 3.03 of this Section, or Engineer approved equal:

Paint Code	Thickness	Description and Acceptable Products
A		Block Fillers for Interior CMU Surfaces:
	100 sq. ft. per gsallon	1. Tnemec Series 130 Envirofill Acrylic Block Filler
B		Top Coat for Interior CMU Walls in Dry Areas:
	5.0 Mils DFT	1. Tnemec Series 161 Epoxoline, Spray-Applied

Paint Code	Thickness	Description and Acceptable Products
C		Top Coat for Interior CMU Walls in Wet Areas:
	3.0 Mils DFT per coat	1. Tnemec Series 66 Epoxoline
D		Barrier Coat for Shop Primed Steel Doors and Frames:
		1. Product and thickness as recommended by manufacturer of top coat, and compatible with shop primer
E		Not Used
F.		First Top Coat for Shop Primed Steel Doors and Frames:
	2.0 to 3.0 Mils DFT	1. Tnemec "No. 27" Typoxy
F1.		Second Top Coat for Shop Primed Steel Doors and Frames:
	1.5 to 2.0 Mils DFT	1. Tnemec "No. 475" Triton
G		First Top Coat for Concrete Walls and Ceilings:
	4.0 to 6.0 Mils DFT	1. Tnemec Series 280 Tneme-Glaze
G1		Second Top Coat for Concrete Walls and Ceilings:
	3.0 Mils DFT per coat	1. Tnemec Series 475 Triton
H		Prime Coat for Concrete Walls and Ceilings:
	3.0 Mils DFT per coat	1. Tnemec Series 201, Tnemec 100% Epoxy
I		Not Used.
J		Signage and Graphics Paint:
	2.5 Mils DFT	1. Mathews "Acrylic Polyurethane"

Paint Code	Thickness	Description and Acceptable Products
K		Concrete Floor Paint:
	4.0 to 6.0 Mils DFT	1. Tnemec 287 Enviro-Tread
L.		Not Used.
M		Prime Coating for Interior Drywall Surfaces:
	One Coat	1. Tnemec Series 51-792 PVA Sealer
N		Top Coating for Interior Drywall Surfaces:
	3.0 Mils DFT per coat	1. Tnemec Series 66 or 161 Epoxoline
P		Interior Metal Handrail and Railing Assemblies:
	1.5 to 2.0 Mils DFT	1. Tnemec "475" Triton
Q		Not Used
R		Not Used
S		First Prime Coat for Structural Steel Exposed to View:
	2.5 to 3.0 Mils DFT	1. Tnemec "594 OmniThane"
T		Second Prime Coat for Structural Steel Exposed to View:
	5.0 Mils DFT	1. Tnemec "27 Typoxy"
U		Not Used
V		Not Used
W		Top Coat for Structural Steel Exposed to View:
	2.0 Mils DFT	1. Tnemec "73 Endura-Shield "

B. Materials Supplied to Authority: Prior to commencing Painting work, the following items shall be provided by the Contractor and shall become the property of the Authority:

2-Each	Dry Film Thickness Gage
2-Each	Elecometer Thickness Gage Scale 1 0-25 thousandths
2-Each	Surface Profile Comparator Kit with Grit Discs

PART 3 - EXECUTION

3.01 INSPECTION

C. If surfaces are not thoroughly dry, or if surfaces cannot be put in proper condition to receive paint or other finish by customary cleaning methods, sanding, or spackling, notify Engineer in writing.

D. Commencing work on any surface will be construed as acceptance of the surface as being satisfactory to properly receive the work of this Section.

E. Furnish and lay drop cloths in all rooms and areas where painting and finishing is being done, to adequately protect flooring and other work from all damage during the painting work.

F. Remove hardware, accessories, device plates, lighting fixtures, factory finished work, and similar items; or provide ample in-place protection. Use skilled mechanics for removal, resetting, and protection.

G. Cleaning: Do not paint over dirt, dust, rust, grease, moisture, or other contaminants detrimental to the formation of a durable paint finish. Clean surfaces thoroughly prior to painting in any given area.

H. Touch up bare or abraded spots on surfaces with shop or existing finishes scheduled to be painted under this Section. Use same material used for shop coat. Substrate shall be smooth, free from raised grain; putty sags, cracks, rust, grease, dirt, or other foreign matter or defect.

I. Incompatible Shop Primers: Remove incompatible shop primers and reprime surfaces, or provide barrier coats in compliance with finish paint manufacturer's instructions.

3.02 SURFACE PREPARATION

D. Concrete and Masonry: Prepare concrete and masonry surfaces prior to painting. Allow a minimum of 60 to 90 days curing time prior to painting poured or precast concrete. Allow a minimum of 30 to 60 days curing time prior to painting concrete masonry. Determine substrate alkalinity and moisture content and take appropriate remedial actions as recommended by paint material manufacturer. Do not paint surfaces which are sufficiently alkaline to cause blistering or peeling until remedial action is taken. Do not paint surfaces where moisture content exceeds that permitted in manufacturer's printed instructions.

1. Wire-brush clean previously painted concrete and masonry surfaces.

2. Thoroughly clean of dirt, grit, loose materials, mortar drippings, and other deleterious substances.

3. Concrete floor which is to painted shall be acid etched and thoroughly washed with a cleaning and degreasing solution, in accordance with the recommendations of the paint manufacturer.

4. The first coat for masonry is a fill coat. Thoroughly brush fill coat into the surface in accordance with manufacturer's directions. Preliminary coats on masonry are to be absorbed into the surface. Provide additional undercoats as necessary to achieve perfect uniformity of finish coats.

5. Where preparation of existing surfaces are required, provide all required dust control procedures to ensure that paint chips, dust, and debris caused by preparation of existing surfaces does not enter the HVAC systems or enter the platform areas, and other habitable areas of the Project.

E. Other Materials: Prepare other materials in strict accordance with recommendations of manufacturers of materials to be finished, and primers and finishes to be applied.

F. Materials Preparation: Mix and prepare paint materials in accordance with manufacturer's printed instructions. Use only thinners approved by paint manufacturer, and only within recommended limits.

3.03 PAINT SCHEDULE

A. Interior wall surfaces of concrete masonry units in dry areas:

Surface Prep: SP-16
Coat 1: Code A
Coat 2: Code A
Coat 3: Code B
Coat 4: Code B

B. Interior wall surfaces of concrete masonry units in wet areas:

Surface Prep: SP-16
Coat 1: Code A
Coat 2: Code A
Coat 3: Code C
Coat 4: Code C

B. Interior wall surfaces of concrete masonry units in wet areas:

Surface Prep: SP-16
Coat 1: Code A
Coat 2: Code A
Coat 3: Code C
Coat 4: Code C

C. Steel doors and frames, etc:

Surface Prep: SP-12
Coat 1: Code D
Coat 2: Code F
Coat 3: Code F1

D. Interior Painted Signage and Graphics on steel doors and frames, etc:

Coat 1: Code J
Coat 2: Code J

E. New and Existing Interior Concrete Walls and Ceilings:

Surface Prep:	SP-14
Coat 1:	Code H
Coat 2:	Code H
Coat 3:	Code G
Coat 4:	Code G1

F. Interior exposed Concrete Floors:

Surface Prep:	SP-14
Coat 1:	Code K
Coat 2:	Code K

G. Exposed to View Structural Steel:

Shop Surface Prep:	SP-6
Coat 1 in Shop:	Code S
Coat 2 in Shop:	Code T
Field Surface Prep:	SP-13
Coat 3 in Field:	Code W

H. Interior Drywall Surfaces:

Surface Prep:	SP-11
Coat 1:	Code M
Coat 2:	Code N

3.04 FIELD QUALITY CONTROL

B. Painting Schedule in this Section lists minimum number of coats required. If specified minimum number of coats does not completely cover or hide base materials, provide additional coats required for coverage and uniform finish appearance, without additional cost to Authority.

C. Apply paint in strict accordance with manufacturer's instructions. Use applicators and techniques best suited for substrates and types of materials being applied. No material shall be thinned in any way except as directed by manufacturer.

D. Apply paints and coatings at coverage rates and dry film thicknesses scheduled in this Section. Each coat applied must be inspected and approved by Engineer prior to application of succeeding coat, otherwise no credit for the coat applied will be given and work in question shall be recoated without additional expense to Authority. Notify Engineer when each coat is ready for inspection.

E. Additional Coats: Provide additional coats necessary to eliminate show through and bleed through conditions.

F. Drying Time: Allow manufacturer's recommended drying time between successive coats. However, allow each coat to thoroughly dry prior to application of subsequent coat.

G. Tinting: Tint prime coat on gypsum wallboard and plaster to approximate color of final shade.

H. Closets: Finish closets inside the same as adjoining rooms, unless otherwise specified or scheduled.

I. Doors and Panels: Paint all doors, panels, access panels, etc., in the "open" position. Paint all edges, tops, bottoms, and both faces. Paint back face of access panels and removable or hinged covers to match adjacent exposed surfaces.

J. Movable Equipment and Furnishings: Paint surfaces behind movable equipment and furnishings same as adjacent exposed surfaces.

K. Duct Interiors: Paint interior surfaces of ducts where visible through registers, grilles, or louvers with flat black, non-specular paint.

L. Finished work shall be free from runs, sags, hairs, defective brushing, and clogging of lines and angles. Flaws visible in the completed work shall be removed and the area satisfactorily repaired.

M. Block Fillers: Apply block fillers to concrete masonry units at rates to ensure complete coverage with pores completely filled.

N. Completed Work: Provide finishes that match approved samples and mock-ups for color, texture, and coverage. Remove, refinish, or repaint work not in compliance with specified requirements.

3.05 CLEAN-UP

B. At completion of work of this Section, remove paint and varnish spots, and oil, grease, and other stains caused by this work from exposed surfaces. Leave finishes in a satisfactory condition.

C. At completion of work of this Section, remove masking materials and other debris. Reinstall or replace fixtures, plates, etc., removed to facilitate application of paint.

D. Retouching: Touch-up and repair applied finishes which, for any reason have been damaged during construction work. All finished work applied under this Section shall have finished surfaces as approved by finish material manufacturer.

E. Final Inspection: Protect painted surfaces against damage until date of Final Acceptance. Engineer will conduct final inspection of painting work. Areas that do not comply with requirements of these Specifications shall be repainted or retouched to satisfaction of Engineer at no additional cost to Authority.

3.06 SURFACES NOT TO BE FINISHED

A. Finishes for the following items are either included under other appropriate Sections or require no painting, except as otherwise specifically scheduled with subsequent Schedules in this Section.

1. Factory finished galvanized steel items.

2. Chrome or nickel plating, stainless steel, bronze, and brass, unless otherwise specified.

3. Factory finished mechanical and electrical equipment, pumps, and machinery, which occur in mechanical or equipment rooms or areas.

4. Galvanized ducts, pipes, conduits, etc., fully concealed from view in the finished work.

5. Factory finished materials, specialties, and accessories unless otherwise specified.

6. Ceramic and clay products, glass, plastic, and other surfaces with "integral" finishes, except as otherwise scheduled herein.

7. Exterior concrete.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM NO.	DESCRIPTION	UNIT
0990.000	Painting	Lump Sum

-END OF SECTION-

SECTION 09910

SHOP PAINTING OF HOT-DIPPED GALVANIZED STEEL

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies substrate surface preparation and shop applied paint systems for structural steel and miscellaneous steel elements which have been hot dip galvanized.

B. Definition: Paint shall be defined as liquid coating applied to the substrate surface by means of conventional air spray, airless spray, brush or roller which dries or cures to a hard surface, and includes the words paint, primer, coating, and words of similar import.

C. All galvanized steel surfaces except the embedded surfaces shall be given epoxy primer and finish coat in accordance with this Section.

1.02 RELATED WORK SPECIFIED ELSEWHERE

A. Documents affecting work of this Section include, but are not necessarily limited to, General Conditions, Supplementary Conditions, and Sections in Division One of these Specifications.

B. Specification sections which directly relate to the work of this section include, but are not limited to the following:

1. Section 04200 - Unit Masonry
2. Section 05041 - Hot Dip Galvanizing
3. Section 05100 - Structural Steel
4. Section 05500 - Miscellaneous Metal
5. Section 09900 - Painting

1.03 QUALITY ASSURANCE

A. Abbreviations:

SSPC - Steel Structures Painting Council
NFPA - National Fire Protection Association
OSHA - Occupational Safety and Health Administration

B. Quality Control: Requirements of Regulatory Agencies: Provide and apply materials complying with environmental requirements of authority having jurisdiction.

1. Required Conference. Arrange a conference to be attended by interested parties including the Engineer, galvanizer, General Contractor, fabricator, Painter, and others whose installed work is specified to be coated under this Section; the purpose will be to discuss conditions, inter-related responsibilities, application and

inspection procedures, specification requirements and other related matters with intention of avoiding misunderstandings and disputes during progress of the work.

2. Thickness Tolerances: Apply coating of specified dry film thickness (DFT) which thickness shall be absolute minimum coverage at any point of measurement as determined by the paint manufacturer.

C. Mock-Up Surfaces or Areas. Sample item may be designated as control for color, texture, and application for each specified paint system. Accepted item will be criteria for acceptance for similar items, which shall match accepted mock-ups.

D. Certificates

1. Provide certificates listing materials used in coating systems and certify compliance with standards designated.
2. Provide certificates stating that materials provided comply with requirements of this section.

E. Inspection - Prior to commencement of this contract the galvanizer shall demonstrate to the satisfaction of the Authority's inspection forces, their capability of fully complying with the intent of these specifications.

1.04 SUBMITTALS

A. Color Selection:

1. Color selection shall be made after award of contract. Colors shall custom match Engineer's sample.

2. Submit minimum three by five inch color chips in accordance with material or finish schedule for selection of colors of each item designated to be painted.

B. Certificates: Submit notarized certificates complying with requirements of this section.

1.05 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Deliver paint materials to galvanizer with label or product data sheet affixed to the manufacturer's containers showing manufacturer's name, type of paint, stock number, batch number, label analysis of solids and vehicle, reducing instructions, thinning instructions, drying and recoat time, application instructions with recommended methods, environmental restrictions and MSDS sheets.

B. Remove permanently from premises containers without labels, or illegible defaced labels.

C. Store paint materials in an accepted location reserved only for such materials and relocated equipment in compliance with applicable health and fire regulations of governmental authorities having jurisdiction.

D. Any containers showing damage to the extent that spillage of contents is visible shall be rejected and removed permanently from the site.

1.06 APPLICATION CONDITIONS

A. Environmental Requirements

1. Apply all intermediate and finish coatings under conditions within the following tolerances:

   a. Air temperature 50 degrees F min, 90 degrees F max.
   b. Surface temperature 50 degrees min, 100 degrees F max.
   c. Relative Humidity 65~ max.

2. Maintain surface dry and free from dust, dirt, oil, grease or other contaminants.
3. Keep environment free of airborne dust and dirt until paint is dry.

4. To ensure compliance with this specification all temperature and humidity levels will be continuously monitored with a recording hydrothermograph. The printed record shall be available for review by the Authority or its representatives at any time during the contract.

5. Both the spray and cure facility shall be in full compliance with all applicable Federal, State, Local, OSHA, EPA, and fire regulations.

6. Spray booth shall have a filtered exhaust.

7. Cure booth may be heated to elevate paint dry time at the applications option, however strictly comply with the paint manufacturer's instructions. Use an indirect thermostat controlled gas fired forced hot air blower. Infra-red type cure equipment shall not be permitted. Temperature shall not exceed 150 degrees F.

8. Spray and cure booth shall be protected by a sprinkler system designed in accordance with NFPA #15.

9. The air in the cure booth shall be continuously monitored by a LEL (lower explosive limit) monitoring device connected to the ventilation system.

PART 2 - PRODUCT

2.01 GENERAL

A. Provide thinners, driers, and other products manufactured, furnished or approved by accepted manufacturers for use with their product.

B. Handle, store, mix and apply paint materials, primers, and metal conditioners, in accordance with recommendations of accepted manufacturers.

C. Should it appear that conflict exists between such recommendations and these Specifications, obtain clarification before proceeding with the work.

2.02 COLORS

A. Provide colors conforming to requirements of one of the following methods as specified in the Construction Specifications.

B. Color selection shall be made after award of contract, as specified in this Section.

C. Provide custom finish coat colors matching Engineers samples.

2.03 MATERIALS

A. Priming and Color Coating of Galvanized Steel Members:

1. All steel that has been hot dipped galvanized after fabrication and is specified to be painted, shall receive a shop applied tie coat and finish color coat as indicated herein.

   a. Epoxy Intermediate Coat: The coat shall be epoxy polyamide formulated for compatibility with newly galvanized surfaces and be equal to Tnemec 27 FC TyPoxy, Dupont Colar 525TL, or Hempel Hempadur 4563. Dry film thickness shall be 2-3 mils.

   b. Polyurethane Top Coat: Top coat applied over epoxy tie coat shall be Acrylic Polyurethane Enamel equal Tnemec Series 74 Endura Shield III, DuPont Imron 333 or Hempel's 551U Urethane. Dry film thickness shall be 1.5-2.5 mils.

2. Scope of Work:

   a. Epoxy Intermediate Coating and Polyurethane Color Coating: All hot-dip galvanized miscellaneous metals, and structural steel items that are exposed to view in the finished work shall have epoxy intermediate coating and polyurethane color coating. Generally, these are items as specified in Specification Sections 05100, and 05500. Work of these Sections that are not exposed to view, and are not exposed to sunlight, shall receive the epoxy intermediate coat only.

PART 3 - EXECUTION

3.01 SURFACE PREPARATION

A. All hot dip galvanized material shall be cleaned in accordance with Steel Structure Painting Council Specification SSPC-SP-1, Solvent Wipe followed by SSPC-SP 7, Brush-Off blast clean to produce minimum 1-1.5 mil profile. Following blast cleaning and prior to application of coating material, the galvanized material shall be visually inspected to determine complete absence of contaminants and that proper tooth or profile exists for paint adhesion. The blasting procedure shall be performed carefully so that the galvanized thickness does not fall below the required 3.4 - 3.9 mil zinc thickness.

3.02 INSPECTION

A. Examine material upon which work specified in this Section is dependent, for defects which may influence application or installation and performance.

B. Do not place work in this Section upon previously placed incomplete, unsound or defective work.

3.03 PAINT SCHEDULE

A. Galvanizer shall apply coating materials to following surfaces as scheduled in the Construction Specifications, SECTION 05041 and as noted on the plans:

Coating System	Thickness	Location or Item
Factory primed only	3 mils min.	For all concealed from view and sunlight galvanized structural steel and miscellaneous metal.
Factory primed with factory applied top coat	2.5 mils min epoxy 3 mils min urethane	For all exposed to view galvanized structural steel, and misc. metal.

3.0 4 APPLICATION

A. All coating material (other than hot-dip galvanizing) shall be applied by the galvanizer or an approved steel fabricator in strict conformance with this Section.

B. Application: Between galvanizing and application of coating materials specified herein, apply coating in min 0 hours to max 12 hours after galvanizing has been applied. Top coatings shall be applied over intermediate epoxy coat in strict compliance with manufacturer's written recommendations.

3.05 FIELD QUALITY CONTROL

A. Inspection:

1. Representative areas will be measured for dry film thickness (DFT).

2. If thickness of coating does not comply with DFT requirements, additional application of paint to attain specified thickness shall be applied at no additional cost to the Authority.

3. Where characteristics of coating prohibits recoating, remove and replace unacceptable coating.

4. Where application of coating exceeds DFT and is determined to be detrimental to the project, remove and recoat to specified DFT, at no additional cost to the Authority. Any repainting will be in strict accordance with Section 1.06.

   a. Where DFT measurement is impractical or impossible, the amount of paint necessary shall be determined from the manufacturer's published spread rate equated to specified thickness.

5. The manufacturer's stock and batch number will be compared with the assigned Paint Identification Number, and color sample submitted for finished surfaces and

with mock-up areas for finished surfaces in accordance with requirements this section.

3.06 FIELD REPAIR PROCEDURES

A. Where factory applied coatings have become damaged or abraded due to handling, transport, installation, welding or other circumstances, they shall be repaired by the field painting crew or miscellaneous metal contractor.

1. All damaged areas shall be thoroughly wire brushed. All dirt, oil, grease or other contaminants shall be removed in accordance with SSPC-SP1 and SP5. Touch-up paint supplied by the galvanizer or steel fabricator, identical in color and composition to that used in the plant, shall be applied to all prepared surfaces to a dry film thickness of at least 3.0 mils.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM NO.	DESCRIPTION	UNIT
0990.450	Shop Painting of Galvanized Steel	LS

-END OF SECTION-

SECTION 10000

MISCELLANEOUS SPECIALTIES

PART 1 GENERAL

1.01 DESCRIPTION OF WORK

A. The work of this Section consists of furnishing and installing the following:

1. Bomb-mitigating trash containers.

1.03 SUBMITTALS

A. Shop Drawings: Submit complete shop drawings of all work of this Section to Engineer for approval, showing all pertinent details of construction and installation.

B. Product Data: Submit complete manufacturer's product data of all work of this Section to Engineer for approval, consisting of complete product description and specifications, catalog cuts, and other descriptive data required for complete product and product use information.

C. Samples: Provide samples of all materials to be exposed in the completed work.

1.04 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Deliver miscellaneous specialties to Project site, fully identified, and protected by padded blankets, scheduled to arrive at time of installation sequence requirements.

B. Store units off ground, under cover, protected from weather and construction operations.

C. Handle units during transportation and installation in a manner that prevents racking or damage to finish or adjacent construction.

PART 2 PRODUCTS

2.01 BOMB-MITIGATING TRASH CONTAINER

A. Provide the following bomb-mitigating trash containers for installation at areas indicated on Drawings as manufactured by Total security Services International, Inc.; Arlington, VA 22203, or approved equal. Metal components shall be stainless steel. All bomb-mitigating trash containers shall be manufactured by the same manufacturer.

1. Provide Stainless Steel Model No. M-10 Bomb Mitigating Container Systems as manufactured by Total Security International, Inc. or approved equal.
2. Provide units with manufacturer's optional frame with locking and disintegrating lids.

PART 3 EXECUTION

3.01 INSTALLATION

A. All items furnished under this Section shall be installed in strict accordance with the approved shop drawings and the manufacturer's printed instructions and recommendations.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the Bomb Mitigating Trash Container work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for Building Specialties.

ITEM NO.	DESCRIPTION	UNIT
1001.000	Building Specialties	LS

END OF SECTION

SECTION 10290

BIRD CONTROL SYSTEMS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies bird control systems as follows:

1. Design and installation of anti-roosting systems by the Installer/Vendor.

1.02 RELATED WORK

A. Carefully examine all of the Contract Documents for requirements which affect the work of this section.

1.03 QUALITY ASSURANCE

A. Source: Provide bird control systems that are the products of one manufacturer. Provide secondary materials that are acceptable to the louver manufacturer.

B. Installer/Vendor shall make recommendations and design and install an anti-roosting system to the satisfaction of the Authority.

1.04 SUBMITTALS

A. Product Data: Submit manufacturer's product data, installation instructions, certified performance data and finish specifications. Provide certifications stating that materials comply with requirements.

B. Shop Drawings: Provide large scale shop drawings for fabrication, installation and erection of all parts of the work. Provide elevations and details of anchorages, connections and accessory items. Indicate joinery, fasteners and all other relevant information.

C. Field Measurements: Take accurate field measurements before preparation of shop drawings and fabrication. Do not delay job progress.

D. Samples: Submit representative samples of each material that is to be exposed in the finished work.

1.05 DELIVERY, STORAGE AND HANDLING

A. Deliver, store and handle in strict compliance with manufacturer's instructions and recommendations. Protect from damage.

B. Sequence deliveries to avoid delays, but minimize on-site storage.

1.06 WARRANTIES

A. Provide a written warranty, signed by the manufacturer, installer, and Contractor, that birds will not perch or roost on the surfaces where anti-perching system is installed in locations indicated on Drawings.

1. Warranty period: 3 years from date of Final Acceptance.

PART 2 - PRODUCTS

2.01 PRODUCTS

A. Anti-Roosting System: Provide Bird Master SprinGuard Anti-Roosting System; as manufactured by Bird Master, Woburn, MA; or equal as manufactured by Nixolite, Cat Claw Inc., or approved equal. System shall consist of 3/16 in. stainless steel spring tensioners; 0.015 in. stainless steel cable; 3mm stainless steel posts, mounted on entire lengths of all horizontal fins and intermediate cornices of the aluminum trellis system. Provide all necessary clips and mounting accessories as required for a complete installation.

PART 3 - EXECUTION

3.01 INSPECTION

A. The Installer/Erector shall examine substrates, supports, and conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning of installation will be construed as installer accepting substrates and conditions.

3.02 INSTALLATION

A. General Installation Requirements: Strictly comply with manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this Section.

B. Installation: Install units plumb, level, in alignment and plane without warp or rack. Anchor securely in place.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Measurement: Work specified in this Section for Bird Control will not be measured but will be paid for under an allowance for Item 1029.103. The allowance will be adjusted to the actual amount paid for all such work. The Contractor shall furnish itemized statements of the work performed and give the Engineer access to accounts, bills, and vouchers relating thereto, and unless the Contractor does furnish such itemized statements, bills, and vouchers, he shall not be entitled to payment for the related work. The allowance will be made to reimburse the Contractor for all services required for the work specified herein.

4.02 PAYMENT

A. Payment: Payment for the work of this Section will be based on itemized statements furnished by the Contractor to the Authority without any mark-up for overhead or profit. No other costs will be paid for work of this Section.

4.03 PAYMENT ITEMS

ITEM NO.	DESCRIPTION	UNIT
1029.103	Bird Control	Allowance

END OF SECTION

SECTION 10400

PORCELAIN ENAMEL SIGNAGE

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing and installing porcelain-enamel station signage, maps and artwork images, as indicated on the drawings and as specified herein.

1.02 RELATED WORK

A. Other specification sections which directly relate to work of this section include, but is not limited to the following;

1. Section 05500 - Miscellaneous Metals; Sign and map frames and supports.
2. Section 10440 - Signage and Graphics; ADA required signage; elevator emergency signage.

1.03 REGULATORY REQUIREMENTS

A. Strictly comply with all applicable codes, regulations and requirements of authorities having jurisdiction.

1.04 QUALITY ASSURANCE

A. Source: Provide primary materials which are the products of a single manufacturer for each type of product or material required by this section. Provide secondary or accessory materials which are acceptable to the manufacturer's of the primary materials.

B. Coordination: Furnish inserts and anchoring devices which must be built into other work. Coordinate delivery of inserts and anchors to trades performing the installation so as to avoid delay in the work.

C. Mock-ups: Before beginning primary work of this section, provide mock-ups at locations acceptable to Engineer and obtain Engineer's acceptance of visual qualities for each type of sign panel. Protect and maintain acceptable mock-ups throughout the work of this section to serve as criteria for acceptance of this work. Provide mock-ups as follows:

1. Provide one 10 ft. x 10 ft. mock-up of each of map panel.

1.05 SUBMITTALS

A. Product Data: Submit manufacturer's technical product data, installation instructions, use limitations and recommendations for each material or product used. Provide certification that materials comply with requirements.

B. Shop Drawings: Submit complete, detailed shop drawings for fabrication, installation, and erection of all parts of the work. Provide plans, elevations, and details of anchorages, connections and accessory items. Show all adjacent work. Provide setting drawings, templates, and directions for installation of anchorage devices.

1. Field Measurements: To the greatest extent possible, take accurate field measurements before preparation of shop drawings and fabrication.

C. Samples: For initial selection, submit full range of samples for each type of unit required, showing colors, textures, and finishes available in the completed work.

1. Verification Samples: Submit 6" square samples of each color and finish on same substrate to be used in the work, showing full range of color, texture and finish to be expected in the completed work.

1.06 DELIVERY, STORAGE AND HANDLING

A. Deliver units cartoned or crated to provide protection during transit and job storage.

B. Inspect units upon delivery for damage. Damaged units will not be accepted.

C. Store units at building site under cover. Place units on minimum 4" high wood blocking. Avoid the use of non-ventilating type plastic or canvas shelters which could create humidity chambers. If packaging of units become wet, remove carton or crating immediately. Provide 1/4" spaces between stacked units to promote air circulation.

1.07 JOB CONDITIONS

A. Substrates: Proceed with work of this section only when substrate construction and penetration work have been completed.

1. Examine substrates, areas and conditions under which work of this section will be applied and notify Contractor in writing of conditions detrimental to proper and timely completion of the work. Do not permit the work to proceed until unsatisfactory conditions have been corrected.

2. Commencing work of this section will be construed as Installer's acceptance of surfaces, substrates, and conditions within any particular area.

PART 2 - PRODUCTS

2.01 PORCELAIN STEEL PLATE

A. Provide ASTM A424 Type 1 vitreous or enameling steel plates with porcelain enamel finish fabricated from an approved low carbon, open-hearth steel, containing a low metalloid and copper content, and capable of retaining a non-metallic, inorganic, fused coating on both sides. Comply with the requirements of the latest edition of "Manufacturer's Standard Practice" of the American Iron and Steel Institute for gage weight, gage thickness and flatness of uncoated sheet.

B. Porcelain Enamel: Provide porcelain enamel comprising of inorganic glasses, frits, glazes and oxides as manufactured by Ferro, Chivit, APEC, Pemco, and Degussa.

Prepare surfaces and apply porcelain enamel at the proper temperatures as recommended by the manufacturer for fusing enamel glass to the surface of the metal panel. Coat steel plates on all surfaces with one coat of grip enamel. Provide one or more cover coats of finish color on front surfaces. Provide a protective enamel coating on all back surfaces and edges.

C. Finish Requirements: Provide uniform porcelain enamel surfaces, free from all bubbles, holes, pits, or other blemishes, imperfections or surface defects.

1. Coating Thickness: Between 0.015" and 0.035" on all surfaces, except edges, corners, and areas receiving several colors.

2. Comply with all requirements of the Porcelain Enamel Institute Standard Tests for Special Properties and Classifications.

3. Provide all panels finished in a minimum of two colors.

D. Hardware: Provide all necessary hardware as follows required to complete the work, and as follows:

1. Bolts, screws and Miscellaneous Fasteners: Brass or bronze.

2. Hangers, Studs, Clip Angles, and Filler Plates: Commercial stock galvanized steel, M10-20.

3. Exposed Fasteners: As indicated above, and tamperproof.

E. Plywood: Provide Exterior Grade A-C Plywood, as graded by APA.

F. All graphics shall be consistent with Authority standards as indicated in "Manual of Guidelines & Standards Volume V". All text shall be Helvetica Medium.

G. Camera ready artwork for the MBTA maps are available from the Authority, at Contractor's cost (Approx. $1,000.00 per map). Any maps shown on Drawings as "SY" and "N" shall be furnished by the Contractor as blank white porcelain enamel panels.

H. All porcelain enamel map panels shall be of laminated sandwich construction consisting of the front sheet of enameling steel laminated to a 1/2 in. marine grade plywood, with a sheet of galvanized steel laminated on the back face.

2.02 GRAPHICS

A. All graphics shall be silk-screened onto the inscription fields prior to final baking of the porcelain enamel surface.

B. Letterforms: Letterforms shall be Helvetica Medium and Helvetica Bold, as illustrated on Drawings. Letterforms shall be clean, sharp, photo-mechanical reproductions from typographic reproductions; hand constructed and hand lettered letterforms will not be accepted; alphabet illustrated on Drawings is for reference only and shall not be mechanically reproduced and used for either sample submittals or the production of the finished signs.

C. Letter Sizes: Letter sizes specified shall be determined by the height of the upper case letter "N". The sizes of finished letters shall conform with the standards for measurement specified on Drawings.

D. Letter Spacing and Word Spacing: Letter spacing and word spacing shall be as noted in MBTA Graphic Guidelines and Standards; alternate spacing will not be permitted.

E. Symbols: Provide camera ready art for all symbols. Art shall be sharp and clean and shall accurately duplicate the symbols shown on the Drawings.

PART 3 - EXECUTION

3.01 INSPECTION

A. The installer/erector/fabricator shall examine all substrates, supports, and conditions under which this work is to be performed and notify Contractor in writing of conditions detrimental to the proper completion of the work. Do not proceed with the work until unsatisfactory conditions are corrected. Commencing work of this section will be construed as acceptance of all substrates and conditions.

3.02 SIGNS

A. Provide sign colors and inscriptions as indicated on the schedules, or as field directed by the Engineer. Porcelain enameled sign plates may be required with a field of more than one color and inscriptions of more than one color.

B. Inscriptions: Place inscriptions properly in the inscription fields and in strict accordance with the approved details shown. Provide full-size layouts of all inscriptions to the Engineer for approval, except for those provided by the Engineer.

C. Field Cutting: Do not field cut porcelain enamel panels.

D. No imprints, characters, shields, trade marks, decals, or other markings containing the name of the manufacturer, contractor, firm or corporation will be permitted on any exposed surfaces.

E. Fabricate enameled signs from pan-formed porcelain enameled steel plate with flat-flanged edges.

3.04 ADJUSTMENT, CLEANING, TOUCH-UP, AND PROTECTION

A. Repair minor damage to eliminate evidence of repair. Remove and replace work which cannot be satisfactorily repaired.

B. Clean exposed surfaces using materials and methods recommended by manufacturer of material or products being cleaned. Remove and replace work which cannot be successfully cleaned.

C. Provide temporary protection to ensure work being without damage or deterioration at time of final acceptance. Remove protections and reclean as necessary immediately before final acceptance.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM NO.	DESCRIPTION	UNIT
1040.200	Porcelain Enamel Work	Lump Sum

-END OF SECTION-

SECTION 10440

SIGNAGE AND GRAPHICS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies signage and graphics as follows:

1. ADA required signs.
2. Access symbols.
3. Elevator and escalator safety signs.
4. Floor delineation in stairways.
5. Room signage.
6. Fire sprinkler room identification (as required to comply with Fire Department Requirements).

1.02 RELATED WORK

A. Carefully examine all of the Contract Documents for requirements which affect the work of this section.

B. Other specifications sections which directly relate to the work of this section include, but are not limited to, the following:

1. Section 09900 - Painting; painting materials and specifications.
2. Section 10400 – Porcelain Enamel signs.
3. Division 16 - Electrical; "Exit" signs.

1.03 INTENT

A. A major intent of the work of this section is to provide colorfast, durable building identification devices as scheduled and as required by codes. Provide all signs and graphics required by authorities having jurisdiction even if not otherwise indicated in the Contract Documents, and as scheduled at the end of this Section.

1.04 QUALITY ASSURANCE

A. Source: For each type of material required for the work of this section, provide primary materials which are the products of one manufacturer. Provide secondary materials which are acceptable to the manufacturers of the primary materials.

1.05 SUBMITTALS

A. Product Data: Submit manufacturer's product data, installation instructions, use limitations and recommendations for each material used. Provide certifications stating that materials comply with requirements.

B. Shop Drawings: Provide large scale shop drawings for fabrication, installation and erection of all parts of the work. Provide large scale layouts of sign wording, spacing, type size and style. Provide plans, elevations, and details of anchorages, connections and accessory items. Provide installation templates for work installed by others. Provide full size spacing templates for individual letters and numbers.

C. Initial Selection Samples: Submit samples showing complete range of colors, textures, and finishes available for each material used.

D. Verification Samples: Submit representative samples of each material that is to be exposed in the finished work, showing the full range of color and finish variations expected. Provide samples having minimum area of 144 square inches or full-size units.

1.06 DELIVERY, STORAGE AND HANDLING

A. Deliver materials and products in unopened factory labeled packages. Store and handle in strict compliance with manufacturer's instructions and recommendations. Protect from damage.

B. Sequence deliveries to avoid delays, but minimize on-site storage.

1.07 SEQUENCING AND SCHEDULING

A. Delay installation of work of this section until near time of Substantial Completion.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Provide products of one of the following manufacturers or equal that meet or exceed the requirements of these specifications:

1. Andco Industries Corp.
2. A.R.K. Ramos Manufacturing Company, Inc.
3. Best Manufacturing Co.
4. Gemini, Inc.
5. Lake Shore Markers.
6. Metal Arts, Division of L & H Manufacturing Co.
7. OMC Industries, Inc.
8. The Southwell Company.

2.02 SIGN MATERIALS

A. Cast Acrylic Sheet: Provide cast (not extruded or continuous cast) methyl methacrylate monomer plastic sheet, in sizes and thicknesses indicated, with a minimum flexural strength of 16,000 psi when tested according to ASTM D 790, with a minimum allowable continuous service temperature of 176 deg F (80 deg C), and of the following general types:

1. Transparent Sheet: Where sheet material is indicated as "clear," provide colorless sheet in matte finish, with light Transmittance of 92 percent, when tested according to the requirements of ASTM D 1003.
2. White Translucent Sheet: Where sheet material is indicated as "white," provide

white translucent sheet of density required to produce uniform brightness and minimum halation effects.

3. Opaque Sheet: Where sheet material is indicated as "opaque," provide colored opaque acrylic sheet in colors and finishes as selected by Engineer.

B. Stainless-Steel Plate, Sheet, and Strip: Provide stainless-steel plate, sheet, and strip, Type 316, complying with ASTM A 666.

2.03 ACRYLIC SIGN FABRICATION

A. Fabricate acrylic signs as follows:

1. Construction: Backplate, 1/8 in. acrylic.
2. Raised Letter Construction: 1/32 in. routed letters permanently mounted to surface of plate.
3. Border Style: None (straight).
4. Background Texture: Smooth.
5. Edges: Eased.
6. Fasteners: Flexible self-adhesive.
7. Beads recessed into material face, glass, brass, or stainless steel.
8. Corners: Square.
9. Braille: Provide raised braille on each sign, as required by ADA regulations.

B. Fabricate work to be truly straight, plumb, level and square with smooth flat surfaces and sharp corners, except where indicated otherwise.

C. Precisely form work to sizes, shapes, and profiles indicated on approved shop drawings.

D. Fabricate acrylic work with uniform, invisible joints.

E. Tactile and Braille Copy: Manufacturer's standard process for producing copy complying with ADA Accessibility Guidelines and ICC/ANSI A117.1. Text shall be accompanied by Grade 2 braille. Produce precisely formed characters with square cut edges free from burrs and cut marks.

1. Panel Material: Opaque acrylic sheet.
2. Raised-Copy Thickness: Not less than 1/32 inch (0.8 mm).

2.04 STAINLESS STEEL SIGN FABRICATION

A. Fabricate stainless signs as follows:

1. Construction: 1/8 in. stainless steel sheet.
2. Letter Construction: 1/32 in. routed or etched letters into surface of sheet.
3. Border Style: None (straight).
4. Background Texture: Smooth.
5. Edges: Eased.
6. Fasteners: Flexible self-adhesive.
7. Corners: Square.
8. Braille: Provide raised braille on each sign, as required by ADA regulations.

B. Fabricate work to be truly straight, plumb, level and square with smooth flat surfaces and sharp corners, except where indicated otherwise.

C. Precisely form work to sizes, shapes, and profiles indicated on approved shop drawings.

D. Tactile and Braille Copy: Manufacturer's standard process for producing copy complying with ADA Accessibility Guidelines and ICC/ANSI A117.1. Text shall be accompanied by Grade 2 braille. Produce precisely formed characters with square cut edges free from burrs and cut marks.

1. Panel Material: Stainless steel sheet.
2. Raised-Copy Thickness: Not less than 1/32 inch (0.8 mm).

2.05 SIGN TYPES

A. Room Signs:

1. Material: Cast-acrylic sheet.
2. Perimeter: Unframed.
3. Character Style: Helvetica.
4. Text: Room name and number, as provided by Engineer.
5. Message: =Fixed.
6. Sizes:

   a. Sign: 4 in. x 6 in.
   b. Character: Minimum 1-inch- (25-mm-) high characters.

B. Toilet Room Signs:

1. Material: Cast-acrylic sheet.
2. Perimeter: Unframed.
3. Copy: Raised.
4. Character Style: Helvetica.
5. Text: According to requirements in the ADA or of authorities having jurisdiction, whichever are more stringent.
6. Message: Fixed.
7. Sizes:

   a. Sign: 4 in. x 6 in.
   b. Character: Minimum 1-inch- (25-mm-) high characters.

C. Stainless Steel Signs: Refer to Drawings for sizes and for copy.

2.04 FINISHES

A. Colors and Surface Textures: For exposed sign material that requires selection of materials with integral or applied colors, surface textures or other characteristics related to appearance, provide color matches indicated, or if not indicated, as selected by the Engineer from the manufacturer's standards.

PART 3 - EXECUTION

3.01 INSPECTION

A. The Installer shall examine substrates, supports, and conditions under which this work is to be performed and notify Contractor, in writing, of conditions detrimental to the proper completion of the work. Do not proceed with work until unsatisfactory conditions are corrected. Beginning work means Installer accepts substrates and conditions.

3.02 INSTALLATION

A. Strictly comply with manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this section.

B. Install work plumb, level, in true plane and alignment. Provide signs and graphics where shown or scheduled using mounting methods indicated.

3.03 TOLERANCES

A. The following allowable installed tolerances are allowable variations from locations and dimensions indicated by the Contract Document and shall not be added to allowable tolerances indicated for other work.

1. Allowable Variation from True Plumb: ± 1/8" in 20'-0"
2. Allowable Variation from True Level: ± 1/8" in 20'-0"
3. Allowable Variation from True Line: ± 1/8" in 20'-0"
4. Allowable Variation from True Plane of Adjacent Surfaces: ± 1/16"

3.04 ADJUSTING, CLEANING AND PROTECTION

A. Adjust work to present the best possible appearance. Touch-up damaged finishes and repair damage to eliminate evidence of repair. Clean exposed surfaces using materials and methods recommended by manufacturer of material or product being cleaned. Remove and replace work that cannot be successfully repaired or cleaned.

B. Provide temporary protection to ensure work being without damage or deterioration at time of final acceptance. Remove protections and reclean as necessary immediately before final acceptance.

3.05 SIGNAGE SCHEDULE

A. Provide signage at the following locations:

1. Each room shall have a Room Number and Name sign, Letter Height - 1 in.;
2. Each floor shall be properly identified in stairways, at each level; Letter Height - 3 in. to 4 in.;
3. Identify each level on elevator hoistway entrance jamb; Letter Height - 4 in.;
4. Elevator and Escalator safety signage at each landing; Letter Height - 1 in.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM NO.	DESCRIPTION	UNIT
1041.400	Sign Work	LS

- END OF SECTION -

SECTION 10450

FARE COLLECTION EQUIPMENT

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the conversion of all rotary arm style fare array equipment to Automated Fare Collection (AFC) Equipment. This work, to be paid for by the Allowance Item 1075.997, shall only be performed if directed by the Engineer. Thru a separate contract with the MBTA, Scheidt and Bachmann (S&B) will be responsible for manufacturing, supplying, delivering, testing, and commissioning of the fare collection equipment to be installed by the Contractor as described herein. The Contractor is responsible to receive, install, run conduit/cable, apply terminations, and test cable/terminations and be available as may be needed during cutover and commissioning of systems.

B. The equipment to be installed at the various locations includes but is not limited to the following:

1. Cash/Credit/Debit/Full Service FVM
2. Cashless FVMs
3. TGH Gate's
4. Accessible TGH Gate
5. Double High Rotary Gate
6. Station Computer/Controller Cabinet and internal equipment (In communication rooms)

1.02 QUALITY ASSURANCE

A. Maintain records of all test and inspection work securely and complete, and keep them available to the Authority during the performance of the Contract.

B. Materials, suppliers, and products shall be subject to inspection to the extent necessary to ensure conformance to technical requirements.

C. The Contractors Quality Assurance Program shall ensure that there is a system for final inspection and testing of completed products. Such testing shall provide a measure of the overall quality of the completed product and shall be performed in a manner, which simulates the product end-use and function.

D. If any damage, defect, error, or inaccuracy is found in any material, component, or any part/parts of the work, the Engineer will have the right either to reject the work or to require correction of the work, which shall be done by, and at the expense of, the Contractor. No separate payment will be made.

1.03 SUBMITTALS

A. The Contractor shall prepare and submit to the Engineer a proposed fare array plan for each fare array location. The shop drawing shall include plans, large scale elevations, sections, details showing all dimensions, materials, methods of construction, and interface methods with adjoining materials. The shop drawing shall be prepared and stamped and signed by a registered architect and shall clearly depict all clearances, equipment locations, egress widths, floor penetrations, fence locations, information kiosk details and locations, and all other pertinent information to properly install the AFC equipment. If existing equipment or obstructions are removed to facilitate the new AFC equipment, the plan shall show how the floor and existing slab penetrations are patched. Samples, product catalogues and

literature, and warranty information of all new finishes shall be submitted. The plan shall also include a complete egress calculation for the station based on the proposed AFC gate arrangements in accordance with NFPA 130 and using the latest peak passenger and average passenger counts provided by the Authority.

B. The Contractor shall prepare and submit to the Engineer for approval shop drawings with calculations stamped and signed by a Professional Structural Engineer registered in the Commonwealth of Massachusetts. The shop drawing shall indicate the installation of all equipment, showing locations, fasteners, reinforcements, base plates, details of fabrication, sizes of members, finishes and all other components that are part of the Fare Collection equipment installation as shown on the contract drawings, and reference documents supplied by the equipment supplier. Fasteners shall be checked using loading information supplied by the equipment manufacturer.

C. The Contractor shall prepare and submit to the Engineer for review and approval proposed electrical drawings, depicting the proposed equipment power requirements, conduit runs, and integration of the AFC gate with the Fire Alarm System. The system shall be designed such that, in the event of a fire, the fire alarm detection system will automatically open all AFC gates. The drawings shall be prepared and stamped and signed by a Professional Electrical Engineer registered in the Commonwealth of Massachusetts.

D. All shop drawings shall indicate by reference the Specification Section number, title, article number and Contract Drawing and sheet number to which the shop drawing pertains. The Contractor shall not fabricate any material or proceed with any equipment installation work until approval of the shop drawings has been obtained. Deviations from the design or reference documents as shown on the Contract Drawings shall be distinctly indicated on shop drawings. Submittal of shop drawings shall comply with the procedures included in these Specifications.

1.04 DELIVERY

A. Shipment of the equipment from the equipment suppliers facility or from the warehouse to the installation site will be the responsibility of the equipment supplier. The Contractor shall coordinate with the Engineer to take delivery of the Fare Collection equipment to be installed.

B. Subway equipment is to be delivered to curb side of the Subway station entrance.

C. The Contractor shall be responsible for all arrangements that are needed for the equipment supplier to access the delivery site and deliver the equipment. The Contractor's responsibility includes but is not limited to making the delivery area available (e.g. snow removal and free space), securing the area (e.g. posting hazard signs if necessary).

D. Details, such as exact address, delivery date, delivery time, number and type of equipment to be delivered will be defined by the Contractor.

E. The Contractor will receive the equipment securely crated and properly labeled. The Contractor shall inspect the equipment for any visible damage to the packaging and crating and note any damage on the delivery receipt form.

F. The Contractor is responsible for equipment after shipment has been made. Transportation from the truck to the installation place and any associated safety precautions for drop-off, transportation and /or interim storage will be the responsibility of the Contractor. Adequately support, block, strap, or otherwise protect components during transportation after shipment.

G. For equipment delivery the equipment supplier will provide standard shipment papers to the recipient with sign-off sheets for documentation purposes. If the Contractor requires any special handling procedures they will need to provide pertinent information to the equipment supplier prior to shipment.

H. The Contractor shall be responsible for providing any means or resources to protect public safety or to secure the system including those maybe needed during unloading of the truck at the curbside during delivery of the equipment.

I. The equipment supplier will notify the Engineer at least 10 days prior to any intended shipment.

PART 2 - PRODUCTS

2.01 GENERAL

A. Cable and fiber optics to be provided shall be in accordance with Sections 16050, 16121 and 16749 and the cable details table provided in the contract drawings.

B. AFC equipment will be furnished by Scheidt and Bachmann.

PART 3 - EXECUTION

3.01 INSTALLATION

A. All material and apparatus specified herein shall be installed in accordance with the Contract Documents, the manufacturer's instructions and recommendations, and in accordance with the Contractor's approved plans.

B. Installation hardware to be provided by the equipment supplier includes anchor bolts, supplies for leveling and sealing, insulation caps for holes in bases of FVM and Validators that feed incoming wires where holes are not used and need to be sealed, and installation templates if needed for installation.

C. Installation hardware delivered by the equipment supplier does not include, standard tools, power supply cables to equipment, communication cables to equipment, wire raceways and tubes to the equipment for incoming power and communication cables, cables between adjacent fare gates, ferrules and connectors as supplies to terminate incoming power and communications cables.

D. Install power wiring from the distribution panel to Fare Collection equipment, in accordance with Contract Drawings, manufacturer's recommendations, and the requirements of these Specifications.

E. Install communications cable (Fiber Optic) from the fiber termination patch panels to the Fare Collection equipment, and the wide area network termination point within the Tel/data room as approved by the MBTA in accordance with Contract Drawings, manufacturer's recommendations, and requirements of these Specifications.

F. The equipment suppliers installation technicians will be responsible for termination of wiring to Fare Collection devices, startup and testing. The equipment supplier is responsible for preparing test reports for commissioning tests.

G. The Contractor is responsible to terminate each cable to its connector where required and shall then test cables in accordance with the applicable section of these specifications. The contractor shall supply suitable cable test reports.

H. TGH gates shall be mounted on a raised floor as shown on the contract drawings. The Contractor shall supply any special anchor bolts required to secure the gates to the raised floor members.

I. The Contractor shall not drill into the floor for mounting of Fare Vending Machines without prior approval of the MBTA. FVM's are to be secured to the base plates which shall be shown on the shop

drawings. These plates shall be fabricated to ensure the machines cannot tip forward when the doors are opened.

J. The Contractor shall install jacks within 6-10 ft cable length of any router locations. This applies to all demarcation points including power. The Contractor shall install cables to demarcation points. The equipment supplier shall connect test and perform final commissioning of equipment. The equipment supplier shall identify the types and number of cables needed between booth and communications room. Fiber cables shall be used.

K. Special Test Requirements for the Contractor such as floor leveling, and cable continuity are described within the equipment installation instructions as provided herein.

L. The equipment supplier will attend site inspections conducted by the MBTA Project Manager to confirm completion of site preparation prior to equipment placement.

3.02 STANDARDS

A. The installation of the Fare Collection equipment shall comply with:

1. The applicable regulations of the Massachusetts State Building Code and the latest Massachusetts Electrical Code.
2. The applicable regulations of the latest National Electrical Code.
3. The applicable regulations of the latest The National Fire Protection Association

B. All electrical materials shall be listed by the Underwriters Laboratories, Inc. as conforming to its standards in every case where a standard has been established for the particular material type.

3.03 TESTING OF COMPLETED ASSEMBLIES

A. Testing of power and communications wire and cable shall be performed. Tests of cross connections between Gate Consoles must provide evidence that each wire is in proper condition. All tests shall be performed in accordance with the applicable Sections of these specifications.

B. After installation of the Fare Collection equipment, the equipment supplier shall perform an Installation Inspection Test on each unit installed to confirm that the equipment is properly installed and interfaces properly with the AFC Central Computer system. All cable tests conducted by the Contractor shall be recorded and those records shall be provided to the MBTA and the equipment supplier prior to commencement of the Installation Inspection Test. The equipment supplier shall inspect all installed equipment for the following:

1. Quality of installation
2. Damage to equipment
3. Missing components and parts
4. Correct power and communication connections
5. Correct positioning and mounting

C. The equipment suppliers technicians shall terminate the power and data cable provided and installed by the Contractor to the equipment termination points. Proper labeling of cables, connectors or conductors by the installation Contractor is required. The equipment supplier shall ensure that records provided by the contractor indicate that the electrical grounding, the power cable protection and the communication capability between the data demarcation points of the field devices and the Central Computer System have been tested and documented by the Contractor prior to the commissioning.

D. Commissioning of the Fare Collection Equipment is the responsibility of the equipment supplier and shall be commenced after receipt of the wiring test records from the Contractor. The MBTA shall be a

witness to the Installation Inspection Test in order to avoid any doubt with respect to the cause of possible damages or inappropriate performance of work.

E. The equipment suppliers commissioning in this context will consist of inspection of proper placement of all inner subcomponents, energizing of the equipment, function test (brief test as per the definition set forth in CDRL 0910), communications test (brief test as per the definition set forth in CDRL 0910). Contractor shall coordinate with the equipment supplier for the details of the test duration.

F. The equipment supplier shall be responsible to energized and commission, all installed equipment and test for proper function and operation.

G. The equipment supplier shall be responsible to perform all communications testing to confirm proper data exchange on all installed equipment.

H. The MBTA's designated representative shall witness all inspections and tests.

I. The Contractor shall be available during functional testing and commissioning to correct any deficiencies that are the result of work performed by the Contractor.

J. Any system deficiencies observed under testing of Fare Collection Equipment shall be noted in the certified test report. The Contractor shall provide a new test report for repaired equipment after all deficiencies are corrected and the system has been retested.

K. Commissioning and Installation Inspection will be conducted in parallel therefore the availability of the MBTA's witnesses is required throughout its execution.

PART 4 - MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. The cost associated with moving the existing fare array from its existing location to be used at the South Head House temporally during stage construction is not include in this Section, and shall be considered incidental to section 2050, Demolition.

B. Measurement for payment of the allowance Item 1075.997, Fare Collection Allowances, will be made to reimburse the Contractor for work and materials performed and supplied by the Contractor and others as specified herein. For construction activities, the Contractor shall coordinate with the Authority Inspector at the end of every day work is done associated with the installation the AFC fare array and equipment. A list of all activities will be prepared. A complete record of all costs, labor, equipment, and materials used each day in performing this work will be created, and will be signed by both the Contractor and the Authority Inspector.

4.02 PAYMENT

A. For the Allowance Item 1075.997, Fare Collection, pertaining to AFC conversion, prior to beginning any work, the Contractor shall request an itemized written estimate of costs from all subconsultants and design firms, utilities companies, and City and State agencies for the work to be performed. The Contractor shall submit these written estimates to the Engineer for review and approval. For work performed by the Contractor, he shall be reimbursed in accordance with MBTA Standard Specifications, Division 1 – General Requirements, Section 01150, Article 1.05, paragraph B.2. The Authority will make no payments exceeding these amounts.

B. Payment for the allowance Item 1075.997, Fare Collection will be based upon receipted invoices and signed receipts, without charges for Contractor overhead and profit, except when the Contractor performs the work, submitted for the actual work performed.

C. The Contractor shall submit receipted copies of itemized invoices for such work to the Authority for partial payments. Payment will be based upon receipted invoices and signed receipts from the utility companies, private firms, subcontractors, or the City and/or State agencies to the Contractor, four (4) copies of which shall be submitted to the Authority.

4.03 PAYMENT ITEMS

Item No.	Description	Unit
1075.997	Fare Collection	Allowance

END OF SECTION

SECTION 10455

ROTARY GATES

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing and installing rotary gates.

1.02 SUBMITTALS

A. Shop Drawings: Submit complete shop drawings with full size details of connections to adjacent work and to structure, as required by the Engineer. Show head, sill and jamb conditions and details of all fabrication and connections.

B. Submit samples of all materials exposed in the finish work.

1.03 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Deliver items to job site as complete units to the greatest extent possible, ready for installation or erection, complete with all anchors, hangers, fasteners and additional items required for installation.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Miscellaneous Steel: Provide mild steel for miscellaneous pieces.

B. Bar Steel: Hot-rolled steel bars, produced in accordance with good mill practice for general and commercial use, Bessemer or open-hearth grade.

C. Structural Steel: ASTM A 36.

D. Through-bolts: Tamperproof heads, stainless steel, as approved by Engineer.

E. Stainless Steel: Type 304, ASTM A 167 Grade 2, with No. 4 satin finish, 1/4" minimum thickness for stainless steel tubes.

2.02 WORKMANSHIP

A. Finish all steel pieces straight, smooth and even, free from defects and of full thickness and weight specified. Grind smooth all exposed welds.

B. Space joints, bolts, screws, rivets, and other fastenings evenly and regularly, and in straight lines. Countersink all exposed rivets and screws, except rivets securing gage metal sheets shall be flattened neatly. Provide hexagonal pattern heads on exposed

heads and nuts of bolts. Cut off all exposed bolt ends flush with nuts. Peen surfaces to prevent loosening. Provide all holes as required to accept work of other trades.

2.03 FABRICATION

A. Fabricate work of this section in a workmanlike manner, true to detail, with clean, straight and sharply defined profiles.

B. Verify and check all measurements at the work site and consult with the various trades installing adjoining work regarding the methods to be employed in connecting the several materials.

C. Do all necessary cutting, drilling and fitting for installation of the work of this section.

D. Except as indicated otherwise, weld all shop-assembled connections. Provide all exposed fasteners of the same metal and finish as items being fastened.

E. Fabricate all work of this section to comply with all OSHA standards and requirements for lateral and vertical loading.

2.04 WELDING

A. Weld all joints continuously. Spot weld only if indicated on the drawings. Dress and grind welds smooth and remove all weld splatter.

B. Provide welds in accordance with the "Standard Code for Arc and Gas Welding in Building Construction" of the American Welding Society.

2.05 SHOP PAINTING

A. Shop Coat: Shop coat all iron and ferrous steel work with a single coat of manufacturer's standard rust inhibitive primer.

2.06 THREE WING HIGH EXIT ROTARY GATE

A. Three-Wing Type: Provide high exit rotary gates of the three-wing type with circular ceiling plate, equipped with emergency release hub and new type gripper arm clamps and exiting in a clockwise direction. Fabricate Type 1 Rotary Gate from Stainless steel components. Subject to compliance with requirements, provide the following type, or equal units as approved by the Engineer:

1. Perey Ful-Stride Type "SA" Impenetrable Roto-Gate.
2. Equal as manufactured by DSI.
3. Equal as manufactured by TomSed Turnstiles

B. Roto-gate shall consist of a rotor, cage, barrier, top cross channel, ceiling plate, top one-way mechanism and bottom bearing plate.

C. Construct Roto-Gate to permit convenient passage of persons through the gate in one direction of rotation only, and positively prevent persons passing through the gate in the opposite direction.

D. Provide one-way mechanisms silent in operation.

PART 3 - EXECUTION

3.01 INSTALLATION

A. The Contractor shall be responsible for proper location of all work of this section.

B. Anchor bolts, sleeves and other incidental items of miscellaneous metals required to be built into the concrete or masonry work shall be furnished to the trades installing concrete and masonry work in time so as not to delay the work. Furnish all necessary templates and installation instructions for installation.

C. Install and erect all work of this section as recommended and instructed by manufacturer, plumb and true to line, finished smooth and free from noticeable irregularities or file marks.

D. Install work of this section in strict compliance with all local code officials. Set and wedge or shim leveling plates to required levels for grouting by the concrete and masonry trades.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for work of this Section, but all costs therefore will be included in the Contract lump sum price for Rotary Gates.

ITEM	DESCRIPTION	UNIT
0548.404	Rotary Gates	LUMP SUM

-END OF SECTION-

SECTION 10800

TOILET ACCESSORIES

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies commercial quality toilet accessories as scheduled.

1.02 QUALITY ASSURANCE

A. Source: Provide toilet accessories which are the products of one manufacturer.

1.03 SUBMITTALS

A. Product Data: Submit manufacturer's product data, installation instructions, use limitations, and recommendations for each material used.

B. Setting Drawings: Provide drawings for installation of all accessories. Provide plans, elevations, and details of anchorages, connections and installation aids. Provide installation templates for work installed by others.

1.04 DELIVERY, STORAGE AND HANDLING

A. Deliver products in unopened factory labeled packages. Store and handle in strict compliance with manufacturers' instructions and recommendations. Protect from damage.

B. Sequence deliveries to avoid delays, but minimize on-site storage.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Provide products of one of the following manufacturers or equal that meet or exceed the requirements of these specifications:

1. Accessory Specialties, Inc.
2. American Dispenser Co.
3. Bobrick Washroom Equipment Co.
4. Bradley Corporation.
5. Charles Parker Co.
6. Watrous, Inc.

2.02 MATERIALS

A. Stainless Steel: AISI type 302/304, with NAAMM no. 4 satin finish, 22 gage minimum.

B. Galvanized Sheet Steel: ASTM A527, G60.

C. Chromium Plating: Nickel and chromium electro-deposited on base metal of steel or brass, ASTM B456, type SC2.

D. Fasteners: Where exposed, provide fasteners finished to match accessory. Where concealed provide galvanized fasteners and mounting kits of type to suit accessory and wall condition.

2.03 FABRICATION

A. Fabricate accessories to be truly straight, plumb, level and square with uniform, tight joints and smooth and rounded edges.

B. Provide units to sizes, shapes, and profiles indicated on approved shop drawings.

C. Provide anchorage arrangement which is fully concealed when unit is closed.

D. Provide continuous stainless steel piano hinges for all accessories that open.

E. Do not apply, stamp or engravé any trademark, trade name or manufacturer's name on exposed surfaces.

F. Provide locks for all accessories that open and provide two keys for each lock. Key all accessories the same.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Strictly comply with manufacturer's instructions and recommendations, except where more restrictive requirements are specified in this section. Beginning work means Installer accepts substrates and conditions.

B. Securely install at heights and locations indicated or if not indicated, at heights and locations as field directed by Engineer. Where toilet room is indicated to be handicapped accessible, install toilet accessories at locations and heights required by authorities having jurisdiction for handicapped accessibility as approved by Engineer.

3.02 ADJUSTING, CLEANING, PROTECTION

A. Adjust operating parts to work easily, smoothly, and correctly.

B. Repair minor damage to eliminate all evidence of repair. Clean exposed surfaces using non-abrasive materials and methods recommended by manufacturer of product being cleaned. Remove and replace work that cannot be successfully cleaned or repaired.

C. Provide temporary protection to ensure work being without damage or deterioration at time of final acceptance. Remove protections and reclean as necessary immediately before final acceptance.

3.03 SCHEDULE OF ACCESSORIES

A. The following catalog numbers refer to products of Bobrick Washroom Equipment Co. and these scheduled products shall serve as the standard of quality required by this contract. Provide these products or comparable products from specified manufacturers if they meet or exceed this standard.

B. Provide the following accessories, one each per toilet room.

1. B-3699: Waste Receptacle and Towel Dispenser.
2. B-2888: Toilet Tissue Dispenser.
3. B-5507.99: Series Grab Bars, non-slip gripping surface, sizes as indicated, and as required to comply with ADA.
4. B-132: Wall Hung Liquid Soap Dispenser.
5. B-290: Mirrors, sizes as indicated.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM NO.	DESCRIPTION	UNIT
1080.000	Toilet Accessories	Lump Sum

- END OF SECTION -

SECTION 11070

EXTERIOR CLOCK SYSTEM

PART 1 GENERAL

1.01 DESCRIPTION

A. This Section specifies electric, exterior clock systems.

1.02 RELATED WORK

A. Examine Contract Documents for requirements that affect Work of this Section. Other Specification Sections that directly relate to Work of this Section include, but are not limited to:

1. Division 16, ELECTRICAL; Conduit, wiring, and other electrical work required for furnishing power supply to systems.

1.03 SUBMITTALS

A. Product Data: Submit manufacturer's printed product data, specifications, standard details, installation instructions, use limitations and recommendations for each material and product used. Provide certifications that materials and systems comply with specified requirements.

B. Shop Drawings: Provide large scale shop drawings for fabrication, installation and erection of all parts of the work. Provide plans, elevations, and details of anchorages, connections and accessory items. Provide installation templates for work installed by others. Show all interfaces and relationships to work of other trades.

C. Field Measurements: Take all necessary field measurements before preparation of shop drawings and fabrication. Do not delay progress of the job. If field measurements are not possible prior to fabrication, allow for field cutting and fitting.

1.04 QUALITY ASSURANCE

A. Source: For each product or material type required for work of this Section, provide primary materials that are products of one manufacturer. Provide secondary or accessory materials that are acceptable to manufacturers of primary materials.

B. Installer: A firm with experience in type of work required by this Section and that is acceptable to manufacturers of primary materials.

1.05 PROJECT CONDITIONS

A. Substrates: Proceed with work only when substrate construction and penetration work is

complete.

1.06 DELIVERY, STORAGE AND HANDLING

A. Deliver materials and products in unopened, factory labeled packages. Store and handle in strict compliance with manufacturer's instructions and recommendations. Store under cover and protect from weather damage.

B. Sequence deliveries to avoid delays, but minimize on-site storage.

1.07 WARRANTIES

A. Obtain standard written manufacturer's warranties in Authority's name for each component of clock systems furnished under this Section where such warranties are offered in published product data, in addition to, and not instead of, other liabilities established by law and other provisions of Contract Documents.

PART 2 PRODUCTS

2.01 MANUFACTURERS AND GENERAL PRODUCT REQUIREMENTS

A. Provide Products as manufactured by one of the following, or approved equal:

1. Electric Time Co.; Medfield, MA
2. Chelsea Clock Co.; Chelsea, MA
3. Van Bergen Bellfoundries, Inc., Charleston, SC

B. Products manufactured by Electric Time Co. are specified herein to establish standards of quality for performance and materials for clock systems.

2.02 CLOCK SYSTEM

A. Clock Components

1. Crystal: clear tempered glass.
2. Dial: Off-White aluminum.
3. Finishes: Hands and dial markings to have a black painted finish; bezel and ring to have a matte black polyurethane finish.
4. Hands: As indicated, or as selected by Engineer.
5. Markings: As indicated, or as selected by Engineer.
6. Movement: Style B28G7-MI Clock Movement Design.
7. Bezel: Spun aluminum bezel
8. Illumination: Off-white neon tube to be provided to light the clock dial from the edge.
9. Listing: Provide UL 48 listing on clock assembly.
10. Diameter: 30 in.

B. Provide Type 99A remote reset control;

1. Control in a NEMA 3R housing.
2. Automatic power fail correction.

3. English Prompting Alphanumeric Red LED display.
4. Built in 100 year Calendar.
5. Automatic Daylight Savings Time correction, no user intervention required.
6. Primary time base to be 60 Hertz line frequency.
7. During power interruptions clock will keep time by means of quartz crystal time base.
8. 10 year battery backup.

C. Lighting Control: Provide PC-25 Intermatic Photoelectric cell, 110 Volts 50/60HZ 25 amps.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install clock system exactly as indicated on approved Submittals, as recommended by manufacturer and specifications.

B. Construct work plumb, level, and true with tight, close fitting joints, securely attached and braced to surrounding construction. Counterbore and predrill for bolt heads, nuts, dowels, and washers where required to avoid interference with other materials.

3.02 TESTING AND ADJUSTMENT AND OPERATION

A. Clock system shall be tested for proper operation and adjusted to run properly.

B. Provide operating and maintenance instructions to Authority.

3.03 CLEANING

A. Upon completion of work in any given area, remove all rubbish and debris from the work area and leave in clean condition.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for work of this Section, but all costs therefore will be included in the Contract lump sum price for Exterior Clock System.

ITEM	DESCRIPTION	UNIT
1657.000	Clock	LUMP SUM

END OF SECTION

SECTION 13126

PREFABRICATED BOOTHS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the following:

1. Fabrication and installation of Starter's Booths and Information Booth as described herein.

2. Work of this Section also includes all glazing, doors, painting, hardware, interior finishes, security systems, electrical systems, HVAC, and millwork, for each booth and enclosure.

3. Provide all security systems required for booths.

B. Including, but not limited to, providing all materials, methods, equipment, specified herein, and installation for the complete booths and enclosures.

1.02 QUALITY ASSURANCE

A. Source: Provide booths and enclosures that are products of one manufacturer. Provide secondary or accessory materials that are acceptable to manufacturers of primary materials.

B. Installer: A firm that is acceptable to the manufacturer of the booths and enclosures.

C. Coordination: Coordinate electrical and security equipment and conduit stub-up locations with requirements of Division 16 before installation of the Booth.

1.03 SUBMITTALS

A. Shop Drawings: Prepare and submit for the Engineer's approval six complete sets of shop drawings which shall indicate all materials, finishes, sizes thicknesses, joint locations, fasteners, edge supports, reinforcement angles, details of fabrication, sizes of members, sizes of glazing, electrical devices and conduits, and all other components that are part of the booth and enclosure work.

1. Do not fabricate any material or proceed with any Work until shop drawings have been obtained.

2. Submit shop drawings showing locations of electrical and mechanical equipment, wireway routing, and installation methods.

B. Samples: Submit two sets of samples of all materials intended for construction to indicate type of finish and workmanship.

1. Submit samples of fabrication methods.

2. Provide requested sample large enough to show typical construction, finish, and workmanship.

3. Submit six 1 ft. x 1 ft. samples of each armor material for testing by the Authority.

1.04 DESIGN STANDARDS

A. The requirements of this Section are based on designs as shown on the Contract Drawings and the Authority's design standards.

1. The configuration of the booths and enclosures and location of principal components shall be as indicated on Contract Drawings.

PART 2 - PRODUCTS

2.01 MATERIALS FOR STARTER'S BOOTHS

A. Metals: Standard Specification Section 05100 and 05500, with modifications and additional requirements as follows:

1. Materials:

a. Metals shall be free from defects impairing strength, durability or appearance and of best commercial quality for each intended purpose.

b. Work shall be clean, straight, and with sharply-defined profiles.

c. Unless otherwise noted, finished surfaces shall have a smooth satin finish.

2. Fasteners:

a. Do not use exposed fasteners on the exterior of the booths and enclosures except where shown for the roof assembly.

b. Interior Exposed Fasteners: Provide of the same material, color, and finish as the metal to which they are applied, unless otherwise shown on the Drawings or specified.

c. Where corrosion-resisting metal is joined to other metals, provide corrosion-resistant fasteners and metal for welding.

3. Aluminum Structural and Trim Shapes: Conforming to FS QQ-A-200/9, Alloy 6063-T5 trim, satin finish.

4. Stainless Steel: Conforming to ASTM, Type 304, 18-8 chrome-nickel alloy, No. 4 satin mill finish.

a. All welds required for construction shall receive matching No. 4 grind; no welds are to show on the exterior; no joints other than those shown are allowed.

5. Steel: Coat by hot-dip galvanizing process and passing ASTM A239.

a. Conform to ASTM Classifications as follows:

Structural Steel: A36.
Structural Tubing: A500, Grade B

B. Millwork: Provide millwork as conforming to the following:

1. General:

a. Grades of all millwork: As defined by the rules of the recognized association of lumber manufacturers producing the materials specified.

b. Materials for Millwork: Conform to or exceed the requirements of "Premium Grade" as established by "Architectural Woodwork Quality Standards", published by the Architectural Woodwork Institute.

c. Lumber and Plywood: Shall, in the raw, bear the grade and trademark of the association under whose rules it is produced, and a mark of mill identification; the material shall be made available for inspection by the Authority before finishing.

d. Wood for Natural Finish Millwork: Select for uniformity of color.

e.

Item	Grade	Kind
Plastic Laminate Countertops and Access Panels	High Density	Particleboard
Cabinets Solid Members	Clear Select	Birch
Plywood	Rotary Cut	Birch

2. Plastic Laminate Countertops:

a. Preveneer countertops fabricated in the shop to dimensions shown.

b. Surfacing: 1/16 in. General Purpose Grade, Class 2 plastic laminate, satin finish.

c. Core: 3/4 in. high density particleboard with solid lumber edge strips as indicated on Drawings.

d. Backing Sheet: 0.020 in. bonded to bottom side of top to prevent moisture absorption and to minimize warpage.

e. All plastic laminate shall meet manufacturer's standard specification for resistance to acids, alkalies, salts, solvents, and burns.

f. Adhesive shall be in accordance with manufacturer's recommendations.

g. Color: To be selected by Engineer from manufacturer's standard range.

3. Cabinet and Casework:

a. Fabricate and install all cabinet and casework indicated on the Contract Drawings for use within the booths and enclosures.

b. Case Doors which are 3/4 in. thick shall have rabbeted edges; 1-3/8 in. or thicker, veneer cores; exposed edges shall have built-in or plowed-in edge bands.

c. Drawers: Fabricate per AWI 400-9, Premium Grade, opaque finish.

d. Cash Drawer: Provide stainless steel dividers per MBTA Standards

4. Plastic Laminate Access Panels:

a. Preveneer panels fabricated to the dimensions shown.
b. Core: 1/2 in. plywood
c. Surfacing: 1/6 in. Vertical Grade.
d. Attachment of Metal Channels: Stainless steel oval head Phillips screws with collars.
e. The rest of the Specification shall be similar to that for plastic laminate countertops.
f. Color Range: To be selected by Engineer from manufacturer's standard range.

C. Building Insulation: Section 07210 of the Standard Specifications.

1. Provide insulation of the type indicated on Drawings. Ceiling insulation shall be 4 in. thick, "R" value of 16.5 minimum. Wall panels shall be 2 in. insulation, "R" value of 8.7 minimum.

D. Vision Panels at Booths: Glazing shall be 1/2" nominal thickness laminated safety glass.

E. Doors: Door assembly shall be constructed of steel, 1-3/4 in. thick with brushed satin stainless steel finish, all welds are ground smooth and filled. Provide fiberglass insulation as noted for wall panel construction. Frame to be welded integrally into booth wall. Door and frame shall be properly reinforced for mortise and surface mounted hardware. Glazing stops to secure to interior side of door.

F. Hardware: Comply with the requirements of Sections 08710, except as modified herein.

1. Materials: All hardware shall be of the best grade materials, entirely free from imperfections in manufacture and finish.

a. Supply all hardware with matching fasteners.
b. All finishes shall match satin stainless steel.

2. Keying Requirements: Key all locksets as directed by the Authority, match existing station keying.

   a. All cylinders shall have removable cores.
   b. Trim: As specified with knobs cast or forged of 0.080 wall thickness.

3. Manufacturers: All hardware shall be made in America and approved by the Authority.

4. Finish Hardware Schedule: Entry Door for each booth shall have:

   a. Hinges: Provide CBP standard #12252 continuous hinge in satin stainless steel finish.
   b. Lockset:: Sargent #7745 mortise x KDA x US 26D with standard Ansi strike and Best Lock Co. removable core cylinder x random key.
   c. Closer: LCN 4040 x Aluminum finish stop side mounted.
   d. Threshold: Dorbin #79A
   e. 2 Mop/Kick Plate

5. Drawers — each Drawer to have:

   1 Pull, US28.
   1 PR Slides.

   In addition to above, Cash Drawer is to have drawer dividers of 18 ga. stainless steel per MBTA standard.

6. Coat Hooks: 2 Stainless steel hooks fabricated by manufacturer of booth.

7. Interior Access Panel to Fare Box — each Panel to have:

   1 pr. Spring Hinges, 2 in. lg.
   1 Transom Catch with Rim Strike

8. Interior Raceway Doors to have:

   Hidden hinges max. 16 in. o.c.
   Security Camlock

9. Casework Doors — each Door to have:

   1 Security Camlock
   2 Hinges, overlay type.

G. Gypsum Wallboard: 1/2 in. thick, fire-rated, ASTM C36, Type X. Provide tape, joint copounds, and installation conforming to the requirements of Section 09250.

H. Metal Ceiling: Provide 24" x 24" perforated aluminum or steel units with color and perforation pattern selected by Engineer. Provide panels fabricated from minimum 0.025 in. thick metal. Provide ceiling panel products of one of the following manufacturers that meet or exceed the requirements of these specifications, or Engineer approved equal:

1. Simplex Ceiling Corp.
2. Steel Ceilings.
3. Architectural Surfaces, Inc.

I. Resilient Flooring: Standard Specifications Section 09650, and as follows:

1. Solid Rubber Tile: 9 in. x 9 in. x 1/8 in. thick or as indicated on the Drawings, color as selected by the Engineer.

J. Painting: Provide painting materials that conform to requirements specified under Section 09900.

K. Air Conditioning: Standard Specifications 15600, Paragraph 2.16, and as modified herein.

1. Air Conditioner Unit: air cooled, 6000 Btu/H, 120 volts, ductless, located above ceiling, with access from within the booth, include a cord and plug connection to the power supply receptacle; provide air conditioner with a 1/2 in. drain line from unit, enclosed down side wall of Booth, to condensate drain line.

2. Wiring shall include a separate wall switch, as indicated on Contract Drawings.

L. Electric Wall Heaters: Standard Specifications 15600, and as modified herein.

1. Heaters: Flush mounted, ductless, 1000 watts (3410 Btu/H) capacity, 120 volt, as indicated on Contract Drawings.
2. Wiring shall include separate wall switches, as indicated on Contract Drawings.

M. Centrifugal Exhaust Fan: 25 CFM, 120 volt, single-phase with damper.

1. As an Alternate, the exhaust fan may be incorporated into the air conditioner unit, as approved by the Engineer.
2. Wiring shall include a separate wall switch, as indicated on the Contract Drawings.

N. Electrical, General: Provide booths with complete interior electrical work installed as Work of this Section. Conform to applicable Sections of Division 16. Include electrical Work for the booths as indicated on the Drawings.

1. Basic Materials and Methods: Standard Specifications 16050 for electrical service and convenience outlets, and as modified herein.

a. Provide empty 3/4 in. steel conduits with pull lines, as indicated on the Contract Drawings, for installation of communications equipment by others.

2. Distribution Panelboards: Standard Specifications 16471, and as modified herein.

a. Booth shall have two panelboards; 120/208 volt, three-phase, four-wire, with quantity of 12 stab-lock type molded case 20 amp circuit breakers as indicated on Contract Drawings.

1) Panelboard No. 1: shall supply all Booth furnished equipment.
2) Panelboard No. 2: shall supply fare collection equipment.

b. Final connection and wiring to Booths electrical service shall be performed by and comply with requirements of Division 16, Electrical.

3. Lighting: Refer to requirements of Section 16500 and to details on Drawings.

4. Booth Intercom Systems: Provide a switchable continuous communication system mounted on transparent armour panel, equal to Model No. TTU-1, as manufactured by Norcon Communications, Inc., Brooklyn, NY, to allow communication between a Starter in the Booth and a person immediately outside. Provide system complete and operational.

5. Provide provisions for a Booth Security System. The booth telephone shall be fed from the alarm panel. Provisions shall be provided for connection to the Verizon demarcation from the alarm panel per Starter's Booth Security System Specification that is specified in Division 16, ELECTRICAL.

6. Public Address System: Provide provisions for public address system interface in the Booth.

7. Fire Alarm Pull Station: Provide provisions for fire alarm pull station in the Booth.

O. Fluorescent Down Lights: Provide one of the following products at all locations that down lights are indicated, with an Osram D26W/41K lamp:

1. Edison Price Dark Lite DTT-26/8, 120 volts.
2. Prescolite CF123526-462.
3. NL RF-1211.

PART 3 - EXECUTION

3.01 PREFABRICATED BOOTHS AND ENCLOSURES

A. Metals: Standard Specifications Section 05100 and 05500, with modifications as follows:

1. Workmanship: Metal surfaces shall be clean and free from mill scale, flare rust, and rust pitting, wellformed and finished to shape and size, with sharp lines, angles, and smooth surfaces. Weld all permanent connections. Welds shall be continuous except where tackwelding is permitted by the Authority.

2. Use screws or bolts only where shown; where used, heads shall be countersunk, unexposed screws will be flathead, screwed up tight and threads shall be niched to prevent loosening. Exposed screws shall be stainless steel oval head Phillips Type.

3. Thickness of metals and details of assembly and support shall give ample strength and stiffness.

4. Provisions for Hardware and Equipment: Panels and Doors shall be prepared by manufacturer for the installation of hardware and equipment. Welding of hinges to frames will not be permitted.

B. Millwork

1. Joints shall be tight and so formed as to conceal shrinkage. Mortise and tenon joints shall be set in glue under pressure within internal angles coped and external angles mitered. Shop miters 4 in. or greater shall be glued and dowelled or locked with a metal splice. Miters less than four inches shall be glued and splined with the spline concealed.

2. All nail heads in finish work shall be sunk 1/16" with a nail set. Panels and siding shall be rigidly secured in place. All exposed screw holes shall be countersunk and plugged with wood. Woodwork shall be properly framed, closely fitted, and accurately set to the required lines and levels and shall be rigidly secured in place.

C. Metal Acoustical Ceiling

1. Metal ceiling shall be installed as per the manufacturer's instructions.

2. Install edge molding along perimeter and to finish off all ceiling edges.

D. Painting and Finishing Standard Specifications Section 09900. Apply painting systems specified herein before.

E. Modular Panel Construction

1. General: Booths and enclosures shall be an assembly of standardized modular panels and base and roof assemblies attached by connector bolts to adjacent panels, roof and base assemblies. Each panel shall be an independent unit which meets specific structural and operational requirements and contains specific optional equipment and associated services while maintaining ballistic integrity.

2. Performance: Booths and enclosures shall be capable of assembly, disassembly and relocation, and selected repairs or replacements by not more than a four-man crew and a foreman with limited hand tools. To accomplish this, booths and enclosures shall be constructed of various panels which shall independently contain, as a minimum: coin change provisions, air conditioner, electric heaters, lighting, lock security, interior/exterior communications, visual alarm, emergency lights and communications, and interior telephone connections. One panel shall provide structural support and attachment for a fare/turnstile. Other panels shall include or provide structural support for interior countertops, cash drawer, coin tray, coat hangers, communication system and control raceway and personal storage drawers, speaker and microphone housing which shall be provided as part of the Booth.

3. Design and Construction:

a. Modular Panels and Sections

l) Each integrated modular panel or roof or base section shall not exceed 500 lbs. or 7'-6" x 8" in size. Each unit will be capable of handling by a four-man crew.

2) The opaque armored panel certified to meet specifications as noted in herein shall be 2" thick, constructed from Shot-Tex #ll-S welded steel construction, as follows:

a) The exterior surface shall be a layer of Shot-Tex #l-S bullet resisting satin stainless steel wall armor.

b) The second layer (internal layer) shall be semi-rigid insulation 2" thick for thermal and sound insulation. Insulation shall provide an "R" factor of 8.7 minimum.

c) The third or interior layer, shall be shot-Tex #l-S bullet resistant stainless steel wall armor.

d) All layers shall be secured with Shot-Tex #l vertical stiffener channels to form a structural panel to meet structural and low thermal conductivity requirements within the 2" thickness requirements.

e) The modular panels shall have watertight joints and fasteners which are accessible only from the interior. The panels shall be joined together through bolted connections and concealed with a removable Shot-Tex #l-S bullet resistant satin stainless steel cover plate applied by hook and loop type fasteners.

4) Vision Panels: Install vision panels at locations indicated.

5) Door Panels: Install door panels and hardware as directed by manufacturer.

6) The modular roof shall be constructed of stainless steel sheet laminated to 3/4 in. plywood with fasteners and an internal layer of fiberglass insulation, 4 in. thick for thermal and sound insulation. Insulation shall provide a U factor of minimum 0.09. Provide fluorescent lighting and an acoustical ceiling suspended by wire supports. Support angles and flanges welded to modular panels and bolted to roof membrane shall secure roof assembly to panelized construction.

7) Flexible fire retardant plastic conduit shall be integral bonded in the modular panels and pre-wired to electrical outlets and switches, and communication and telephone connections. The modular panel will not contain junction boxes or internal inaccessible connections.

8) Coordinate with Electrical Sections and provide for emergency gate release switches and pilot lamps.

F. HVAC Installation: Install air conditioning units within booth ceilings with removable stainless steel louvers for servicing.

1. Air Conditioning: Standard Specification Section 15600 and as modified herein:

a. Mount air conditioners above ceilings within booths at the location indicated on Contract Drawings or as directed by Engineer.

b. Drain line running from air conditioning unit shall be connected to a floor drain provided by station contractor in a secure manner so that the line cannot be accidentilly removed.

c. Unit shall be controlled by wall switch, as indicated on Contract Drawings.

2. Electric Wall Heaters: Standard Specification Section 15600 and as modified herein:

a. Heaters shall be controlled from wall switches, as indicated on Contract Drawings.

b. Manufacturer shall provide two flush mounted electric heaters.

G. Electrical

1. Base Materials and Methods: Standard Specification Section 16500.

2. Make provisions in pre-fabricated walls for raceways and conduits. Pre-cut electrical outlets and other required openings.

3. Distribution Panelboards: Standard Specification Section 16471 and as modified herein:

a. Locations of panelboards shall be as indicated on Contract Drawings.

4. Lighting: Standard Specification Section 16500.

5. Booth Intercom: Install booth intercom systems complete and operable in accordance with the following:

a. National Electrical Code
b. MBTA Manual of Guidelines and standards
c. Manufacturer's recommendations

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

ITEM NO.	DESCRIPTION	UNIT
1077.075	Prefabricated Booths and Enclosures	Lump Sum

- END OF SECTION -

SECTION 14240

HYDRAULIC ELEVATORS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the furnishing of all labor, materials, and equipment with experienced supervision for the delivery, assembly of elevator EV-1 and (EV-2 as an Add-Alternate as explained below) with all systems and all incidentals, installation, system operation, testing and ready for use elevators as specified herein and in accordance with the Contract Documents.

B. Add-Alternate No. 3: The base bid includes the construction of the elevator pit, pit drainage , CMU reinforced shaft walls, temporary lower level door screen, concrete, concrete grade slab to cap the top of the elevators shaft below grade. This Add-Alternate includes all costs for the furnishing of all labor, materials, and equipment with experienced supervision for the delivery and assembly of one elevator (EV-2) with all systems connected for operation as described in this Section. In summary, the alternate includes elevators equipment, doors, pit ladder, mechanical support, and elevators Headhouse.

C. During this Project modification to the Maverick Station, the Station will remain open during construction. The relationship of each Phase of construction phasing to its predecessor and successor stages is critical to maintain Station egress. Since the installation of each elevator in its scheduled Phase is critical to the construction schedule for physically challenged pedestrians, the elevator(s) must be fabricated, installed, obtain an operation certificate from DPS/EID and open to the public in accordance with the Phase of construction as shown in the Contract Documents. The elevator Manufacturer/Installer is required to coordinate with the Contractor and complete the elevator(s) within the Contractors scheduled time frame.

D. The work covered in this Section shall be coordinated and complimentary performed with the work of other trades included, but not limited to Article 1.03, Related Work Specified Elsewhere.

1.02 TEMPORARY AND PERMANENT ELECTRICAL POWER SERVICES

A. Electric service for the elevator system shall be 480 volts, AC, 3 phase, 4 wire, 60 hertz terminating in a disconnect switch in the elevator machine room. Provide the Power Supply Confirmation Data Form listed as Attachment "A" according to Article 1.09 Submittals.

B. Electric service for lighting and 20 ampere duplex receptacles shall be 120 volts, AC, single phase, 3 wire, 60 hertz terminating in the elevator pits and remote machine rooms at a junction box located so that the light switches and receptacles can be used without passing over any part of the machinery.

1. All electrical wiring for power and elevator operation conduits systems for EV-1 and EV-2 from its adjacent machine room to the Inbound Platform and to and within the hoistway shall be weatherproof.

C. Electric power during the installation of the elevators shall be suitable to provide illumination, operation of required tools and hoists and sufficient current for starting, testing and adjusting the elevators. T to final testing. For each elevator, all power, temporary and permanent, shall be provided at no additional cost to the Department until the elevator has been inspected and accepted for public use.

1.03 RELATED WORK SPECIFIED ELSEWHERE

A. The Contractor shall coordinate all disciplines indicated in Related Work to ensure that the new Elevators are tested, inspected and fully operational prior to the elevators opening for public use. Related Work includes, but is not limited to, the following:

1. DIVISION 1 – General Requirements
2. Section 02050 - Demolition
3. Section 03300 - Cast-in-Place Concrete
4. Section 03604 - Non-Shrink Construction Grout
5. Section 04200 - Unit Masonry
6. Section 05041 - Hot Dip Galvanizing
7. Section 05100 - Structural Steel
8. Section 05500 - Miscellaneous Metals.
9. Section 07101 - Waterproofing and Dampproofing
10. Section 07145 - Cementations Waterproofing
11. Section 07210 - Building Insulation
12. Section 07920 - Sealants and Caulking
13. Section 08800 - Glazing
11. Section 09900 - Painting
12. Section 10440 – Signage and Graphics
13. Section 15020 - Temporary Construction Ventilation
14. Section 15050 - Basic Materials and Methods for Mechanical Work
15. Section 15400 - Plumbing Systems
16. Section 15600 - Heating, Ventilation and Air Conditioning
17. Section 16050 - Basic Materials and Methods
18. Section 16120 - Wires and Cables
19. Section 16170 - Disconnects and Circuit Breakers
20. Section 16450 – Grounding
21. Section 16460 – Transformers
22. Section 16500 - Lighting
23. Section 16620 - Emergency Power Systems
24. Section 16710 - Fire Alarm and Detection System
25. Section 16750 - Elevator Emergency Intercom System
26. Section 16770 - Public Address System

1.04 DEFINITIONS

A. Authority having jurisdiction: Local jurisdiction Agency and/or Department responsible for issuing certificates for use, inspections (including but not limited to the various agencies of the Department of Public Safety and Boston Fire Department, and the Agency and/or Department witness for required testing. Authority having jurisdiction is used consistently and shall not be misinterpreted for the term Authority, meaning the MBTA (see the definition of Department).

B. Code: A citation of the codes, standards, publications and other references listed in Article 1.05 of this Section.

C. Complete Set: Shop Drawings shall be submitted as a complete set which includes, but not limited to all items in Article 1.09 SUBMITTALS and all other reference to submittal requirements within this Specification.

D. Contractor: The General Contractor for the specified Project/Contract. The General Contractor is responsible for all coordination between the various trades and associated Specification Sections for the elevator installation and operation. The General Contractor is also responsible for all his subcontractors to perform the work, tests and inspection as specified within this Section.

E. Device or a Part of the Equipment: Reference to a device or a part of the equipment applies to the number of devices or parts required to complete the installation.

F. Elevator Manufacturer/Installer: The party selected under this Contract to furnish and to install the elevators as a subcontractor to the General Contractor under this Project/Contract. The phrase of Elevator Manufacturer and/or Installer implies that the manufacturer is also the installer or the installer is approved by the elevator manufacturer for the installation of the elevators as specified within this Specification.

G. Elevator Nomenclature: ASME/ANSI A17.1, Safety Code for Elevators and Escalators.

H. Installer: Either the elevator manufacturer or an approved licensee of the manufacturer, who has not less than five years successful experience with the installation of elevators, and who is currently under contract for maintenance of elevators in the area, and who maintains a service center within 50 miles of the project site.

I. Letter of Certification: Submitted letter shall be Notarized with requested compliance and signed by an Officer of the Manufacturer and/or Installer as specified.

J. Project Representative: This "Project" consists of representatives from the MBTA, Architects and Engineers. Various submittals within this Section require review, decisions and information from these representatives that provide resultant review status of the required submittals listed in this Section.

K. Special Tools: Tools designed specifically for tasks associated with elevator examinations, maintenance, and repair, or those which are required for these tasks and are not readily available through normal purchasing channels.

L. Station: all levels include Street, Mezzanine, and Platforms (Inbound and Outbound).

M. System: Includes all elevator components and equipment and incidentals specified within this section, unless otherwise used in context with a referenced system. The system is also inclusive of elevator components not specified in this Section but provided with the manufacturer's elevator operating system.

1.05 APPLICABLE CODES, STANDARDS AND PUBLICATIONS

Note: The latest editions of codes, standards and publications shall be used for all criteria listed within this Article and Section. Where there is conflict with the codes listed below or any portion of the Specification, the more stringent regulation and requirement shall govern. In all cases, Code shall be the governing factor.

A. Acceptable Manufacturers

1. Hydraulic Elevators: Delta/Beckwith, KONE, Fujitec America, or accepted equal.

B. Physically Challenged Accessibility Requirements

1. The Massachusetts Architectural Access Board (MAAB) and the Americans with Disabilities ACT (ADA).

C. The American Society of Mechanical Engineers (ASME) and the American National Standards Institute (ANSI) latest edition

1. ASME/ANSI A17.1, "Safety Code for Elevators and Escalators"; except Section 800 (governed by NFPA 130) and except as modified by 524 CMR: Section 35.00 The Commonwealth of Massachusetts Board of Elevator Regulations shall be the governing codes.

2. ASME/ANSI A17.2: Inspectors Manual for Elevators and Escalators.

3. 527 CMR12.00 Massachusetts State Electrical Code: All electrical equipment and wiring shall conform to the requirements of 527 CMR.

4. ANSI Z97.1: American National Standard for Safety Glazing Materials Used in Buildings - Safety Performance Specifications and Methods of Test.

5. ASME/ANSI A17.5-M 1991/CAN/CSA-B44.1 Standard for Elevator and Escalator Electrical Equipment.

6. ASME/ANSI QEI-1 Standard for the Qualifications of Elevator Inspectors

D. AISC - Specification for the Design, Fabrication and Erection of Structural steel for Buildings.

E. American Institute of Steel Construction (AISC)

1. AISC - Specification for the Design, Fabrication and Erection of Structural Steel for Buildings.

F. American Society for Testing and Materials (ASTM)

1. ASTM A36: Specification for Structural Steel.

2. ASTM A167 REV A-89: Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip.

3. ASTM A123: Galvanizing

4. ASTM A325: Standard Specification for High Strength Bolts for Structural Steel Joints.

5. ASTM A446: Standard Specification for Steel Sheet, Zinc Coated (Galvanized) by the Hot-Dip Process, Structural (Physical) Quality.

6. ASTM A490: Standard Specification for Heat Treated Steel Structural Bolts, 150 kg Minimum Tensile Strength.

7. ASTM A500: Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.

8. ASTM A501: Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing.

9. ASTM B221: Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes.

10. ASTM C1048: Standard Specification for Heat Treated Flat Glass - King HS, Kind FT Coated and Uncoated Glass.

G. American Welding Society, Inc. (AWS)

1. AWS D1.1: Structural Welding Code Steel Twelfth Edition.

2. AWS A2.4: Standard Symbols for Welding, Brazing and Nondestructive Examination.

3. American Standard Booklet Z-49.1, Safety in welding and cutting provides recommendations for ventilation during cutting or welding of galvanized materials.

H. National Fire Protection Association (NFPA)

1. NFPA No. 130, "Fixed Guideway Transit Systems"

2. NFPA No. 51B, "Standards for Fire Prevention in Use of Cutting and Welding Process"

3. NFPA No. 70, National Electric Code with modifications by 527 CMR, Massachusetts State Electric Code.

1.06 JOB CONDITIONS

A. Field Measurements

1. The Contractor with the elevator manufacturer/installer shall verify that the field measurements for each elevator (immediately after each opening is prepared for the elevator installation) and prior to drilling for the casement of the in-ground plungers as indicated on the approved elevator shop drawings and Contract Drawings.

B. Coordination Requirements

1. Coordinate installation of floor opening construction.

2. Coordinate floor /finish at the elevator doorsill finish elevation with the required pocket for sill installation. The elevator manufacturer/installer shall coordinate with the Contractor for the elevator's required eight (8) inch extended doorjamb opening until the rails and doorframe are installed.

3. Coordinate elevator heating and ventilation for all the elevators. Contractor shall coordinate with other appropriate trades for the installation of heaters and ventilating fans where required.

4. Coordinate lock and key requirements: Contractor shall coordinate with the Engineer and the Authority.

5. Coordinate elevator pit.

C. Protection: During installations, and until elevator systems are fully operative, Contractor shall make necessary provisions to protect systems from damage, deterioration, and environmental conditions.

1.07 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Deliver materials in manufacturer's original, unopened protective packaging.

B. Store material in original protective packaging. Prevent soiling, physical damage, and wetting. Storage shall be provided in a manner recommended by the manufacturer.

C. Protect equipment and exposed finishes during transportation, erection, and construction against damage and stains.

1.08 QUALITY ASSURANCE

A. Regulatory Agencies: Elevator design, materials, construction clearances, workmanship, and tests shall conform to the requirements of the codes and regulations listed in Article 1.05, APPLICABLE CODES, and STANDARDS AND PUBLICATIONS

B. Working: Welding shall be performed in accordance with the requirements of AWS D.1.1. Welders shall produce evidence of current certification by the American Welding Society.

C. Tolerances

1. If field measurements are found not to be the same as shown on the approved elevator shop drawings for each elevator, Contractor shall perform minor structural alterations, or modify mechanical systems as required, at no additional cost to the Department.

2. In the event of a discrepancy, the Contractor shall notify the Engineer immediately, and shall not proceed with installation in the areas of discrepancy, until the discrepancy has been fully resolved, and the Engineer has instructed the Contractor to proceed.

3. Failure of Contractor, Elevator manufacturer and/or installer to report discrepancies shall constitute an acceptance of existing work as fit and proper for the execution and completion of Contractor's, Elevator manufacturer and/or installer's work.

D. Labeling Requirements: Each elevator and associated equipment within the machine rooms shall be labeled as designated within the Contract Drawings, such as EV-1 and EV-2.

E. Requirements of Authority Having Jurisdiction

1. Application, Permits, Tests and Inspections

a. Elevator Manufacturer and/or Installer shall obtain and pay for all permits, and perform such tests with all required equipment and material and/or retests as may be required for acceptance and approval of each elevator by the Authority having jurisdiction. The Elevator Manufacturer and/or Installer shall complete all retesting due to improper coordination, preparation, or failure of previous tests at no additional cost to the Department.

b. Elevator Manufacturer and/or Installer shall notify the Department, Engineer and proper inspectors to witness required a minimum of four (4) working days is advance of the scheduled inspection.

1.09 SUBMITTALS

A Submittals and shop drawings shall be furnished no later than sixteen (16) weeks (112 calendar days) after the Contractor has been provided the Notice to Proceed unless otherwise directed by the Department.

B. The general layout drawings covering the elevator installations shall be provided and no work shall commence before these drawings are approved by the Engineer.

C. Submittals and shop drawings shall be furnished as a "complete set" set for each item as required for submittal within this Section. Eight (8) sets of each submittal shall be provided unless additional sets are specifically required elsewhere in the Contract Documents. Incomplete sets are not acceptable. Shop Drawings shall have one reproducible vellum within the eight (8) required Submittals.

D. The Contractor shall submit a letter from the Elevator Manufacturer indicating that the Installer is approved and authorized by the Elevator Manufacturer for the installation of the elevators as specified for this Project. The letter shall be signed by an Officer the Manufacturer. If the manufacturer intends to install the elevators, it shall be submitted in letter form and signed by an Officer of the Manufacturer.

E. All proprietary equipment for the elevator shall be clearly identified in the Manufacturer's literature and manuals provided in Article 1.09/N. Proprietary equipment shall not be manufactured with decaying circuits, software and hardware requiring new and or reprogrammed information for complete use of the elevators as specified in this Section. All equipment included in the elevator installation shall have maintenance service tools and/or equipment, repair or replacement parts readily available and accessible to the Authority or their authorized representative for elevator maintenance. Without limitation, this shall include but not be limited

to solid state boards, controller components, piston, and motor and pump components required for the operation and maintenance of the installed elevator equipment system.

F. The Elevator Manufacturer shall provide a letter of certification indicating that the elevator system as submitted in Article 1.09, SUBMITTALS has taken no exceptions to the Contract Specification unless otherwise directed and/or approved by the Engineer. If the manufacturer intends to install the elevators, it shall be submitted in letter form and signed by an officer of the Manufacturer.

1. Elevator manufacturer/installer shall provide a separate letter of certification that no proprietary equipment as explained in Article 1.09/E has been installed for the elevators specified in this Section. Letter format shall coincide with the above paragraph.

G. The Contractor shall coordinate delivery to the site, or other storage area acceptable to the Engineer, and provide adequate secured storage acceptable to the elevator manufacturers, installers and the Engineer for the new Elevators. The storage area or areas proposed by the Contractor must conform to the recommendations of the elevator manufacturers. Stored elevators and related equipment shall be insured as required by the Contract Documents.

H. Submit to the Authority having jurisdiction elevator plans and documents according to their requirements. The Contractor shall provide a copy of the letter of transmittal to the Engineer of all documents that was provided to the Authority having jurisdiction by the Elevator Manufacturer/Installer. When the Elevator Permit number is assigned for each elevator, the number shall be forwarded to the Engineer.

I. After the elevator has been installed, inspected, tested and issued a license for public use by the Authority having jurisdiction, the Elevator Manufacturer/Installer shall provide a letter of certification indicating that the elevator system installation as submitted and approved in Article 1.09, SUBMITTALS has taken no exceptions to the Contract Specifications during the installation unless previously directed and/or approved by the Engineer.

J. Submit chart with proposed dates for the new Elevators EV-1 and 2 delivery and installation for each elevator. Shop Drawing delivery (assume a three (3) week review period by the Engineer) the chart shall provide the following after shop drawings have been approved:

1. Weeks for Fabrication time and expected delivery to site.

2. Weeks for Installation time based on consecutive installations of elevators and specify how elevators are proposed installation method, consecutive or simultaneous.

3. Weeks for any other critical items.

4. Weeks for Inspection and testing and/or retesting

K. Product Data: Submit manufacturer's product data, installation instructions, use limitations and recommendations for each product and system used. Provide manufacturer's certifications stating that products and systems comply with requirements. List and describe features of control system, performances, and operating characteristics.

1. Manufacturers with Catalog Cuts: Fixtures, 2-Speed exhaust fan, door operator, full door height electric eye, motor pump assembly, controller, holeless hydraulic plunger, immersion dipstick heater for the oil storage tank, threshold heater, intercom system for communication between the COP and elevator machine room, door weather stripping and hoistway door entry security locks for Elevator EL #2 at Street Level.

2. Manufacturer's color selection for exposed surfaces as defined within Article 2.02 MATERIALS, E, Paint, for elevator car and equipment and hoistway.

    a. Submit paint samples on scheduled material for all observation elevators.

L. Shop Drawings: Provide large-scale shop drawings (minimum of 3/4" equals 1'-0" unless otherwise noted) for fabrication, installation and erection of all parts of the work. Provide plans for each machine room, hoistway, and car in addition to elevations, and details of anchorages, connections and accessory items. Provide installation templates for work installed by others. Provide detailed information on the holeless hydraulic jack assembly and installation. Provide details on pit beam, hoistway entrances, buffer, and information on the rail reactions. Provide the following information:

1. Rail and jack reactions for each type of holeless hydraulic piston assembly along with loads imposed on the building shall be submitted with calculations stamped by a Professional Structural Engineer registered in the Commonwealth of Massachusetts.

2. Scaled, Fully Dimensioned Layouts: Plan of pit, hoistway with overhead and machine room indicating equipment arrangement, elevation section of hoistway with detail of rail attachment to the structure.

    a. Design Information: Indicate equipment lists, reactions and design information on layouts.

    b. Dimension clear distances from the top of the crosshead to the underside of the structure and any projections within the hoistway in addition to the centerline of Jack, rails and platform from clear hoistway walls.

    c. Dimension clear distances from the underside of the car sling to the pit floor and buffer.

3. Scaled, fully dimensioned layouts and interior elevations of each car: Plan of car showing the clear inside-car dimensions used to calculate the weight capacity of the car, and showing the arrangement of the elevator control panel, doors, direction indicator, elevator intercom system between the COP and Machine Room, and other related items. Provide reflected ceiling plan for the car locating the exhaust fan, emergency exit, lighting and other related information.

    a. Sections and details of car roof, including the relationship of the emergency exit and hatch with the exact location of the crosshead.

    b. Detail of jack attachment to car.

    c. Observation car enclosure (EV-1 and 2) detailed section with floor, intermediate, and ceiling

4. Submit dimensioned drawings of the car operating panel (COP), position and floor indicator landing control stations, firefighter's keyed switch, access key switch. Combination Position Indicator and Hall Lantern, Elevator Supervisory Panel and emergency power operation, elevator intercom in the COP (By the elevator manufacturer/installer) and hook-up of the COP elevator emergency intercom system by others in Section 16750 and other related information.

5. Complete Attachment "A" entitled Power Supply, Confirmation Data Form from the National Elevator Industry Incorporated (NEII) 7th Edition of their publication entitled Vertical Transportation Standards, page 38. Attachment "A" includes one (1) page and listed as page 33 of this Section. Submit Attachment "A" for all elevators and submit with the first elevator submittal.

M. Submit the following material samples with designated gauge, finish material and applicable elevators:

1. **Floor: _" stainless steel Pattern RTL.**

2. Stainless Steel Plate with designated finish for landing control stations, door frame, door, interior car panels, handrail with wall connection.

a. Samples shall be no less than 3 inches by 5 inches and shall be labeled on the unfinished side with the location and elevator for which the material will be used

N. Submit the following:

1. As built wiring diagrams: Submit no later than three (3) weeks after the elevators receive a certificate of operation for public use.

2. Instruction and maintenance manuals. All proprietary equipment for the elevator equipment shall be clearly identified in the manufacturer's literature and manuals.

3. Recommended spare parts list.

O. Acknowledge and/or respond to drawing markup within twenty-one (21) days of return; promptly incorporate required changes due to inaccurate data or incomplete definition so that delivery and installation schedules are not affected. Revision response is not justification for delivery or installation delay.

1.10 PERMITS, TESTS AND INSPECTIONS

A. Obtain all permits, licenses inspection and fees necessary to complete each elevator installation at no additional expense to the Department. See Article 3.08, ACCEPTANCE INSPECTION AND TESTS for additional information and requirements.

B. Perform, at no additional cost to the Department, all tests, re-tests and inspections required by the Elevator Inspection Department, ASME/ANSI A17.1, and ASME/ANSI A17.2 in the presence of the Engineer and other individuals with jurisdiction.

C. Supply the required personnel and equipment and materials for tests, inspections and final reviews at no additional cost to the Department.

1.11 MAINTENANCE AND WARRANTY

A. The approved maintenance service consisting of regular examinations, adjustments and lubrication of the ell elevator equipment shall be provided by the elevator manufacturer/installer for a period of 12 months following the day the elevator is made available for public use by the Authority as part of the Contractual requirements. Maintenance shall include, but not be limited to, the following:

1. Scheduled preventive maintenance in accordance with the manufacturer's recommendations.

2. 24-hour emergency callback service.

3. Systematically examine adjust, clean and lubricate all equipment.

4. Repair or replace defective electrical and mechanical parts using parts produced by the manufacturer of installed equipment.

5. Make good any defects not due to ordinary wear and tear or improper use, which may develop during the warranty period.

6. Maintain elevator machine rooms, hoistways, and pits in clean condition.

7. Use competent personnel supervised and employed by the elevator installer.

B. Submit for acceptance by the Project Representative a detailed service maintenance program, showing functions to be performed and their scheduled frequency with the first submittal as scheduled in Article 1.9 after being awarded the Contract.

C All work shall be performed during regular working hours of regular working days of the elevator trade, except that emergency minor adjustment callback service shall be provided during any regular or overtime hours at no additional cost to the Owner should the Project Representative notify the Contractor.

D Required Download Data Storage

1. The manufacturer and/or installer shall download all information from the elevator(s) faultfinding device and diagnostic equipment information collection systems onto a PC laptop and disk. This procedure shall occur immediately after the Authority's Inspection and has approved the elevator system followed every six (6) months as a condition for the recording of events.

2. The Elevator Manufacturer and/or Installer shall download all the diagnostic data recorded events from the controller to a PC laptop then copy these files onto a disk. The disk shall be accurately labeled showing the assigned escalator number along with date of download. Submit the disks and their printouts (hardcopy) to the Owner's designated representative

within two (2) weeks after each of the recording procedures is completed. Provide a copy of the same printouts transmitted to the Owner into the "record log" binder.

3. The elevator manufacturer and/or installer shall include all required hardware, software, parts and experienced labor to correct system malfunctions except for those repairs, replacements, or adjustments.

4. The elevator manufacturer and/or installer shall maintain all the elevator printouts at a designated area at the Terminal. The information shall be organized by date, descending order within binder(s) the two (2) printouts maintenance data reports for each escalator installed in this Contract

E. The manufacturer's required calibrations and battery replacements performed annually shall be done so at no cost to the owner for one annual required update.

1.12 TEMPORARY USE OF ELEVATORS BY THE CONTRACTOR

A. The Contractor shall not use new elevators in the Station construction without the written permission of the Engineer. Use of the elevator by the Contractor will only be considered after the elevator has received an operational license by the Elevator Inspection Department. If Contractor is permitted to use an elevator before its final acceptance for public use, the Contractor shall sign a Contractor's Temporary Acceptance Form documenting that use of the elevator is at the Contractor's own risk and that the Contractor accepts responsible for maintenance and protection of that elevator, including but not limited to, necessary guards or other protection for the elevator hoistway and entrances, mainline wiring, elevator operators, and necessary repairs resulting from damage incurred by the Contractor's use. The Contractor's expenses related to the Contractor's use of elevators shall be no additional cost to the Department.

PART 2 - MATERIALS

2.01 ELEVATOR SCHEDULE

A. The overhead and travel dimensions provided in this Section are furnished as a quick reference for the traveling and operation criteria. The dimensions provided in this Article 2.01 are approximate, as indicated by the ± symbol, and the actual dimensions must be verified with the Contract Drawings.

B. ELEVATOR EV-1

Service:	Passenger, Class A
Capacity:	3,000 lbs
Speed:	100 fpm
Entry:	Front (north) @ Street Level - Unpaid
	Rear (south) @ Platform Level - Unpaid
Car Height:	8 feet 0 inches clear height
Interior Car Size:	60 inches W x 80 inches D. (33.35 S.F.)
No. of Landings:	2 Street and Platform
No. of Openings:	2
Door Type:	2-Speed Slide 3 feet 6 inches wide
Door Opng:	7 feet 0 inches
Operation:	Collective

Travel:	15 feet 10 inches ± (Verify with Contract Drawings)
Overhead	13 feet +
Pit Depth:	4 feet 6 inches
Type:	In-ground Plunger
Motor:	50 H.P.
Pump Unit Type:	Dry Mount Power Type
Power Supply:	480V, 3 Phase, 4-wire, 60 Hertz A.C.
Machine Room Location:	Adjacent hoistway west wall @ Platform
Main floor:	Street Level - Unpaid
Alternate floor:	Platform Level - Unpaid

Special Features:

Usage Classification – High - 120 stops per hour (sph)
Observation Car
Glass Doors
Door Operator that does not have moving/stationary arms within the glass area
Diagnostic Programmable Controller w/ integral soft start- NEMA 4X (Type 316)
Low Profile Car Sling (that does not impede emergency exit hatch operation per Code
Immersion type heater dipstick in the oil storage tank
Threshold Heater at Street Level
Emergency Power Operation and override switch at Street Level
Medical Emergency, Firefighters', Independent and Inspection Service
Two-Speed Exhaust Fan with built-in emergency battery back up, NEMA 4X (Type 316). COP hook-up of the Elevator Emergency Intercom System and Intercom communication between machine room and COP (by the elevator manufacturer/installer).
Homing Level – Platform (this feature shall be able to be turned on or off without reprogramming the elevator).
Heat Exchanger
Scavenger Pump

C. ELEVATOR EV-2 (Add Alternate No. 3)

Service:	Passenger, Class A
Capacity:	2,500 lbs
Speed:	100 fpm
Entry:	Front (north) @ Street and Platform Levels - Unpaid
Car Height	8 feet 0 inches clear height
Interior Car Size:	68-inches W x 60-inches D. (28.35 S.F.)
No. of Landings:	2 (Street and Platform Levels)
No. of Openings:	2
Door Type:	Center Opening (3'-6")
Door Opng:	7 feet 0 inches
Operation:	Collective
Travel:	24 feet 10 inches ± (Verify with Contract Drawings)
Overhead	13 feet ±
Pit Depth:	4 feet 6 inches
Type:	Holeless Roped Hydraulic
Motor:	40 H.P.
Pump Unit Type:	Dry Mount Power Type (120 sph)

Power Supply:	480V, 3 Phase, 4-wire, 60 Hertz A.C.
Machine Room Location:	Adjacent hoistway west wall @ Platform
Firefighter's Keyed Switch Operation	
Main floor:	Street - Unpaid
Alternate floor:	Platform Level- Unpaid

Special Features:

Usage Classification - High - 120 stops per hour (sph)
Observation Car
Glass Doors
Door Operator that does not have moving/stationary arms within the glass area
Diagnostic Programmable Controller w/integral soft start- NEMA 4X (Type 316)
Low Profile Car Sling
Immersion type heater dipstick in the oil storage tank
Threshold Heater at Street Level
Emergency Power Operation and override switch at Street Level
Medical Emergency, Independent and Inspection Service
Two-Speed Exhaust Fan with built-in emergency battery back up, NEMA 4X (Type 316),
Hook-up of the Elevator Emergency intercom System and elevator Intercom communication between machine room and COP (by the elevator manufacturer/installer).
Homing Level – Platform (this feature shall be able to be turned on or off without reprogramming the elevator).
Heat Exchanger
Scavenger Pump

2.02 MATERIALS

A. Steel

1. Sheet Steel (Furniture Steel for Exposed Surfaces): Stretcher-leveled, cold-rolled, commercial-quality carbon steel, complying with ASTM A366, matte finish.

2. Sheet Steel (for Unexposed Surfaces): Hot-rolled, commercial-quality carbon steel, pickled and oiled, complying with ASTM A569.

3. Structural Steel Shapes and Plates: ASTM A6, ASTM A36, and ASTM A108.

B. Stainless Steel: **All stainless steel shall be Type 316** with thickness as designated in this Section and hardness required for fabrication, strength and durability. Mechanical finish on fabricated work shall be provided with textures and reflectivities specified and in the locations shown or specified in the Contract Drawings. Adhesive-paper covering shall protect finishes.

1. Finish designation 1: #4, directional polish, satin finish. Graining directions in longest dimension.

C. Aluminum: Extrusions per ASTM B221; sheet and plate per ASTM B209.

D. Fire Retardant-Treated Particleboard Panels: Minimum 3/4 inch thick backup panels, edged and faced, and provided with suitable antiwarp backing; and conforming to ASTM E84 Class I rating with a flame-spread rating of 25 or less.

E. Paint shall conform to the Authority's Standard Specification Section 09900:

1. Primer: One coat zinc-rich, two component urethane primer, with metallic zinc content of 83% by weight in dry applied film; solids by volume of 63.0 +/- 2.0% (mixed); and dry film thickness of 2.5 to 3.5 mils per coat; volatile organic compounds of 2.69 lbs. per gallon.

2. Topcoat: One coat hi-build epoxoline, corrosion-resistant, epoxy-polyamide coating with dry-film thickness of 4.0 to 6.0 mils per coat; solids by volume of 56.0 +/- 2.0% (mixed); volatile organic compounds of 3.02-3.08 lbs. per gallon; mixing ratio by volume of One (Part A) to One (Part B).

a. Color will be selected by the Engineer from manufacturer's standard colors.

2.03 ELEVATOR PERFORMANCE

A. Speed: +/- 10% of contract speed under any loading condition.

B. Capacity: Safely lower, stop and hold up to 125% of rated load.

C. Stopping Accuracy: +/- 3/8 inch under any loading condition.

D. Floor-to-Floor Performance Time: Seconds from start of doors closing until doors are 3/4 open and car level and stopped at next successive floor under any loading condition or travel direction (12 feet 0 inches typical floor height): 13.5 seconds unless otherwise designated within the Code and/or ADA Requirements.

E. Pressure: Design and factory test fluid system components for shall be in accordance with the manufacturer's recommendations do not exceed operating pressure recommended by the manufacturer.

2.04 OPERATION

Elevators supplied shall be capable of the following:

A. Operate elevator without an attendant from buttons in car and at each landing. When elevator is idle, automatically start car, dispatch to other landing, or open doors depending upon location of registered call. Dispatch car to other terminal when the car or hall button for that landing is pressed. Retain calls registered when car is in transit; allow time for passenger transfer, then dispatch to other terminal. Illuminate push-button when call is registered; extinguish light when call is answered.

B. Door Operation: Open doors automatically when the car arrives at a floor to permit transfer of passengers. Automatically close doors after a timed interval according to ADA and MAAB physically challenged codes and standards.

C. Automatic Stopping Accuracy: Two-way automatic with re-leveling feature to stop the car within 3/8 inch above or below the landing sill. Capable of adjustment to limit overtravel and undertravel and maintain stopping accuracy within Code requirements regardless of load in car or direction of travel.

D. Independent Service: Provide controls for operation of each elevator from car buttons only. Close doors by constant pressure on desired destination floor button. Open doors automatically upon arrival at selected floor.

E. Low-Oil Control: In the event oil level is insufficient for travel to the top floor, provide controls to return elevator to the main level and park until oil is added.

F. Motion Control: AC type with unit valve suitable for operation specified and capable of providing smooth, comfortable acceleration, retardation and dynamic braking. Limit the difference in speed between full load and no load to not more than +/- 10% of the contract speed.

G. Standby Lighting and Alarm: Car-mounted, battery unit with solid-state charger to operate alarm bell and lighting, per code. Battery to be rechargeable with 5-year minimum life expectancy. Provide test button in service cabinet of car station which causes illumination of standby lighting bulbs. Locate lights so they are part of normal car lighting system or not exposed to view.

H. Provide operating systems that will enable each elevator to perform as designated in Article 2.01 ELEVATOR SCHEDULE, according to Code.

I. Firefighter's Keyed Switch Operation: Provide a remote key switch within Room 103 – Police that will enable all the elevators to be activated into the Firefighter's Operation Mode.

J. Door Entry Security

1. EV-1 and 2: The doors shall be capable of locking out unauthorized entry into the Station from the Street Level.

a. Door entry security shall be performed by manual key switch operation (hall and car station locations).

b. Exterior key switch in the landing control stations shall be a weather resistant type and vandal resistant.

K. Homing Level (EV-1 and 2 – Platform Level (this feature shall be able to be turned on off without reprogramming the elevator).

2.05 MACHINE ROOM EQUIPMENT

A. Arrange equipment in spaces shown in Contract Drawings. Provide identifying numbers on pump unit, controller, and disconnect switch corresponding to the elevator identification designated in this Contract (i.e. EV-1and EV-2) besides the MBTA master elevator numbering system.

B. Elevator Power Unit: The hydraulic pump unit system shall be of compact design suitable for operation under the required pressure, not to exceed 400 p.s.i. The pump unit shall not be mounted in the hydraulic fluid storage tank. The pump shall be driven with a one piece multi-groove V-belt. The direction valve shall control flow for up and down directions hydraulically and shall include an integral check valve. A control section including control solenoids shall direct the main valve and control: up and down starting, acceleration, transition from full speed to leveling speed, up and down stops, pressure relief and manual lowering. All of these functions shall be fully adjustable for maximum smoothness and to meet contract conditions. System to be provided with a muffler and a low-pressure switch and internal tank heater with on-off switch and pilot light identifying that it is on. Provide a single lever ball type shut-off valve in both the machine room and the elevator pit. The power unit shall be tested at the factory and CSA and UL approved.

C. Selector: Relay, solid-state or moving crosshead type electrically or mechanically coupled to elevator car.

D. Controller: Provide a programmable logic controller (PLC) with diagnostic features to operate the elevator(s) as described in Article 2.01 Elevator Schedule. The controller shall be non-proprietary such as; such as Allen-Bradley, Rockwell Automation, General Electric, Siemens, Mitsubishi. . Identifying symbols or letters identical to those on wiring diagrams permanently marked adjacent to each component on the controller. Controller shall be wall mounted. Provide reduced voltage motor solid state "soft start" starting circuits. Controller shall be wall mounted.

1. The elevator shall be provided with a controller located in the designed machinery rooms shown on the Contract Documents and approved elevator layout shop drawings. The elevator controller shall be housed in a totally enclosed, wall mounted, Type 304 stainless steel, NEMA 4X (Type 316) cabinet. A cabinet cooling system shall be provided in the enclosure for properly ventilating it without the contamination of outside air. Hinged gasketed doors shall be provided for access to the front panels. Door(s) shall be of pan type and shall have not less than 3/4-inch deep-formed edges to assure stiffness.

2. The controller switches and other equipment shall be mounted on panels of sufficient thickness to support the weight and minimize vibration. The panels shall be securely mounted on substantial self-supporting Type 304 stainless steel frames.

3. The elevator controller shall utilize a programmable microprocessor based logic system and shall comply with ASME A17.1 safety code for elevators. The system shall provide the means to access the computer memory for elevator diagnostic purposes, and shall have permanent indicators as an integral part of the controller to indicate important elevator statuses.

   a. The PLC shall be designed with all necessary hardware and software to communicate over Ethernet or approved equal.
   b. The PLC racks shall provide space for two (2) future single slot modules.
   c. The PLC in the remote control panel shall also have hardware and firmware provisions to communicate with interactive operator_interface (monitor).

4. The diagnostic system shall be capable of for transmitting, storing downloading information of a minimum of the last one hundred (100) stoppages concerning safety devices and faults shall be furnished and installed. Provide a terminal to download information onto a lap top PC.

5. Include built-in noise suppression devices, which provide a high level of noise immunity on all solid-state hardware, and devices.

6. Under no circumstances, shall the safety circuits be affected by accidental grounding of any part of the system. Design the system so that it will start properly when power is restored in the event of a power failure or interruption.

7. Provide system memory so that data is retained in the event of power failure or disturbance.

8. Controller shall have all the necessary relays, transformers and system operation features for the hook-up to the elevator supervisory panel in Room 103 - Police and hook-up to the Programmable Logic Controllers (PLC) in the Station Communication Room for system wide monitoring.

9. **The controller for EV-2 shall be designed to operate the security lock out at Street Level hall station and within the car.**

10. The controller shall have an integral keyboard for reprogramming and diagnostic use.

E. Muffler: Provide in discharge oil line near pump unit. Design to dampen and absorb pulsation and noise in the flow of hydraulic fluid.

F. Piping and Oil: Provide piping, connections and oil for the system. Use isolated couplings between the pump unit and oil lines. No vitolic couplings are allowed

G. Shut-Off Valve: Manual valve in line adjacent to pump unit. Provide second valve in pit adjacent to jack unit(s).

H. Noise and Vibration Control

1. To minimize noise and vibration in occupied areas, mechanically isolate elevator equipment from the structure and electrically isolate controllers and motor.

2. The noise level for elevator equipment in operation shall not exceed 60 dba in elevator cars under any operating condition including door operation and exhaust blower on highest speed.

I. Heat Exchanger: An external air blast oil cooler shall be supplied for each elevator based on its operating criteria as described in Article 2.01. The elevator manufacturer shall submit calculations and BTU output documenting the heat generation for the type of elevator use at 120 sph. The cooler shall include an adjustable thermostat control, 10-micron filter, capable of remote installation, pump, a cooling unit with a motor designed for 3-phase voltage. The cooler mounting at the tank end.

2.06 HOISTWAY EQUIPMENT

A. All hoistway equipment specified within this Article shall be designed and constructed with material and equipment of weatherproof classification.

B. Pipe Rupture Valve: A pipe rupture valve shall be supplied and installed on the oil line. It shall be located as close as possible to the cylinders inlets. In the event of failure in the main cylinder line or where the down speed exceeds allowable limits, the rupture valve shall closes, bringing the car to a smooth stop.

C. Pipe Supports: Piping shall be supported so as to prevent undue stresses at joints and fittings, particularly at any section of the line subject to vibration

D. EV-1 Driving Components and Connections: The driving machine connections shall be:

1. A standard direct plunger hydraulic type installed in a hole drilled into the ground beneath the elevator car. Drilling and its coordination is the responsibility of te elevator manufacturer/installer.

2. Manufacturer's standard direct lift cylinder, single acting plunger and cylinder assembly designed for the pressure resulting from load and speed requirements of the elevator.

3. Capable of withstanding with its attachments, without damage, any forces resulting from a plunger stop or safety application.

4. Plungers: Plungers shall be fabricated of seamless steel tubing, carefully turned and polished in accordance with the manufacturer's standards. The plunger and connecting couplings for the plunger shall be of materials with a factor of safety of not less than 5 based on the ultimate strength and with an elongation of not less than 10 percent in a length of 2 inches. When the driving machine is subjected to eccentric loading, the plunger connection to the car shall also be designed and constructed so that:

   a. It will transmit the full eccentric movement into the plunger with a factor of safety of not less than 4.

   b. The total vertical deflection of the loading edge of the car platform due to eccentric loading of the car will not exceed 3/4 inch.
      (1) Carry in tension the weight of all plunger sections below the joint with a factor of safety of not less than 4,
      (2) Transmit in compression the gross load on the plunger with a factor of safety of not less than 5 based on ultimate strength,
      (3) Withstand without damage any forces resulting from a plunger stop

5. Cylinders: Cylinders shall be fabricated of steel tubing. The cylinder and connecting couplings or the cylinder shall be of materials with a factor of safety of not less than 5 based on the ultimate strength and with an elongation of not less than 10 percent in 2 inches. Clearance shall be provided at the bottom of the cylinder so that the bottom of the plunger will not strike the safety bulkhead of the cylinder when the car is resting on its fully compressed buffer.

6. Exterior of below ground cylinders shall be protected by near white blast cleaning, followed by manufacturer's standard rust inhibitive primer plus paint system totaling 3 mil dry film thickness, triple wrapping of 4 mil, minimum, carbonated polyethylene film, each applied with rubberized asphalt compound at least 56 mils thick.

7. Manufacturer's standard babitted lined or bronze plunger guide bearings and oil seal assembly with drip ring and wiper shall be provided. Cylinder support brackets shall be welded to cylinder walls.

8. Cylinder Heads and Plunger Heads: Closed heads of cylinders, and heads of plungers subject to fluid pressure, shall conform to the following requirements:

   a. Closed Cylinder Heads: Closed heads of cylinders shall be of dished seamless construction, concave to pressure, except if the bottom of the cylinder is supported, and if the cylinder is not below ground.

   b. Dished Seamless Heads, Convex to Pressure: Dished seamless heads, convex to pressure if used on plungers, shall have maximum allowable working pressure of not more than 60 percent of that for heads of the same dimensions with pressure on the concave side.

   c. Reinforced Heads: Reinforced heads shall be designed and constructed so that the maximum stress at rated capacity shall not exceed 12,000 psi for mild steel and one-fifth of the ultimate strength of the material for other metals.

9. Metal Stops: Metal stops and/or other means shall be provided at one end of the plunger and at the packing head end of the cylinder to prevent the plunger from traveling beyond the limits of the cylinder. The metal stops and/or other means shall be so designed and constructed as to stop the plunger traveling in the up direction at maximum speed under full load pressure, should the normal terminal stopping device fail to operate, or at a reduced speed when an emergency speed limiting device is provided.

10 Connections: The connections to the driving machine, plunger, plunger connection, couplings, or any other parts of the hydraulic system shall be designed and constructed to withstand, without damage, a plunger stop or safety application.

11. Connections: The connections to the driving machine, plunger, plunger connection, couplings, or any other parts of the hydraulic system shall be designed and constructed to withstand, without damage, a plunger stop or safety application.

   a. The inner casing shall be closed on the bottom and be watertight. Casing shall be designed with adequate tolerance to permit accurate centering and plumbing up, plus 1 inch additional diameter for every 15 feet, or fraction thereof, of cylinder depth in excess of 20 feet.

   b. Casing shall be extended a minimum of 4 feet below bottom of cylinder. Clean casing inside and out of loose rust and scale, and paint with rust inhibitive coating of 2 mils, minimum, dry film thickness.

   c. Exterior seal water stop flange shall be provided for encasement in concrete floor or elevator pit.

12. Liner: A polyvinyl chloride (PVC minimum schedule 80) liner shall be furnished and installed for the cylinder. The liner shall be capped at the bottom and all joints shall be solvent welded or heat welded to obtain water tightness.

13. Union Guard 180: Provide agent between the cylinder and PVC line in accordance to the Union Guard 180 installations instructions.

E. EV-2 Driving Components and Connections: The driving machine connections shall be:

1. The system shall be that of a holeless roped hydraulic having a rotating sheave to be mounted to fixed shaft through ball or roller bearings. Sheave support base to be attached to top of plunder with single 1-1/4" UNC bolt. Adjustable rope retainers shall be provided over the full 180 degree arc of contact. Sheave to be supported by two rails through cast aluminum slipper guides with removable UHMW polyethylene gibs. Suspension ropes and connections shall comply with ANSI A17.1-2000, Section 2.20. Ropes to be pre-stretched 8x19 construction with independent wire rope core. Shackles to be of the wedge rope socket type. A manually reset switch shall remove power from the driving motor and control valve should any rope become slack.

2. Governor and Safety: Supply as required by code. No remote testing of the safety is permitted

3. Cylinder Mounting Assembly

   a. Base of cylinder to be elevated above pit floor by a pedestal weldment, including : (1) dead-end hitch plate for pit shackles, and (2) mounting surface for slack rope switch.

   b. Pedestal and cylinder to be secured to wall by a steel bracket around the full 360 degree circumference, to fasten to the wall mounting surface with two horizontally spaced bolts, and adjustable for widthwise, depthwise, and vertical adjustment.

4. Cylinder: The cylinder shall be constructed of steel pipe of sufficient thickness and suitable for the operating pressure per section 2.1. The top of the cylinder shall be equipped with a cylinder head with drip ring and self-adjusting packing. The plunger shall be constructed of selected steel tubing or pipe of proper diameter machined true and smooth with a fine polished finish. The plunger shall be provided with a stop ring electrically welded to it to prevent the plunger from leaving the cylinder. The plunger and cylinder shall be installed plumb and must operate freely with minimum friction.

5. Oil Line Support Stands: Oil line support stands shall be supported with an adequate number of support stands. Stands shall be anchored to the floor or wall and adjustable in height. Rubber isolation clamps shall secure the oil line to the stand around the full 360-degree circumference.

6. Low Pressure Switch: low pressure switch to be pre-installed to valve

F. Automatic Oil Return System (Scavenger Pump): automatic oil return system shall be provided capable of pumping return oil to system tank. A reservoir and copper tubing shall be utilized to return oil to system tank, and pump shall have a 100-micron filter. All tubing shall be properly tied down or supported.

G. Guide Rails: Planed steel T-sections suitable for elevator travel, car weight, and with brackets and all necessary bracket assembly extensions for attachment to the building structure. Provide backing to meet Code requirements. Guide rail brackets shall be provided by the Elevator manufacturer/Installer sized to fit in hoistway as shown in the Contract Drawings. Rail weights or rail backers shall be used to allow rail brackets to span from floor to floor to the centerline of floor structure to which the bracket assembly will be attached. Rail brackets and extensions shall be used to secure rails to building structure when necessary engineered to safely sustain rail reactions per code.

H Buffers: Spring type with blocking and supports, minimum of three (3) buffers per car unless a greater number is required by Code.

I. Normal and Final Terminal Stopping Devices: In accordance with Code.

J. Electrical Wiring and Wiring Connections

1. Conductors and Connections: Copper throughout with individual wires coded and connections on identified studs or terminal blocks. Use no splices or similar connections in wiring except at terminal blocks, control cabinets, junction boxes, or conduits. Provide 10% spare conductors throughout. Provide four pairs of shielded communication wires in addition to those required to connect specified items. Run spare wires from car connection points to individual elevator controllers in the machine room. Tag spares so they can be identified in the machine room.

2. Conduit and Duct: Painted or galvanized steel conduit and duct. Conduit size: 3/4-inch minimum. Do not use flexible conduit exceeding 36 inches in length. Flexible heavy-duty service cord may be used between fixed car wiring and car door switches for door protective devices.

3. Flame and moisture-resistant outer cover. Traveling cables including all extra cable spares are to be of the shielded wiring type. Prevent traveling cables from rubbing or chafing against hoistway or elevator equipment within hoistway. Provide four (4) extra cables spares with pull wires within the traveling cable for future hook-ups. Traveling cable shall be weatherproof.

4. Life Safety: Connect smoke sensors, elevator emergency intercom, elevator intercom, jacks and speakers to designated point adjacent to hoistway or in machine room according to the Contract Documents.

K. Entrance Equipment

1. Door Hangers: Two-point suspension with upthrust adjustment. Tire rollers so that no metal-to-metal contact exists.

2. Door Tracks: Bar or formed, cold drawn steel with smooth hanger contact surface. Provide removable tracks or track surface for replacement.

3. Interlocks: Provide type operable without retiring cam. Paint interlocks flat black.

4. Closers: Spring, counterweight or spirator type.

5. Items 1 through 4 above shall include but not be limited to the requirements of this paragraph for providing weatherproof systems for each elevator. All electrical wiring for power and elevator operation conduit systems for each elevator from the machine room to and within the hoistway shall be weatherproof.

L. Pit Stop Switch: In accordance with Code.

M. Floor Numbers: Stencil painted yellow, 4 inches high floor numbers within the hoistway in accordance with Code

2.07 HOISTWAY ENTRANCES

A. Entrances: Hoistway entrance consisting of doors and frame assembly shall be bearing a two (2) hour UL fire label. The items as listed in this Article are included in this Section by the elevator manufacturer and/or installer.

B. Frames: Fabricated from not thinner than 14 U.S. gauge stainless steel with a #4 finish and a smooth, consistent joint/finish on exposed face only and shall consist of head and jamb section with integral casing or trim, all welded/bolted to form a one -piece unit. Permanently attach physically challenged floor designation two (2) inches high, raised 0.030 inch stainless steel #4 finish with lettering/number style and color selected by the Engineer, 60 inches above the floor at both jambs. Stick-on or riveted plates are unacceptable.

1. Rough walls shall not be erected within eight (8) inches of each jamb until the rail and door alignment relationship has been established.

C. Door Panels: Doors shall be flush and formed from not lighter than No.16 U.S. gauge 1-HM rigidized stainless steel #4 finish on the exposed face only to match the interior car door panel other face of panel shall be formed from not thinner than No. 16 U.S. gauge furniture steel. All joints shall be welded full length and shall contain suitable material for sound deadening. Bottom of doors shall be provided with removable phenolic guides to run in sill slots with minimum clearance. All doors shall be reinforced and provided with keyways as required by the door mechanisms and to meet Code and other regulations having jurisdiction. Doors shall be reinforced for separate hangers.

D. Sight Guards: 14 U. S. gauge material, same material and finish as hoistway entrance door panels.

E. Sills: Extruded nickel silver.

F. Sill Support Angles: Structural or formed shape shall be hot-dipped galvanized designed to support the sill with grouting.

G. Fascia, Dust Cover, and Toe Guards: Fascia plates, dust covers and toe guards shall be constructed of not thinner than No. 14 U.S. gauge steel, reinforced to insure flat even surface throughout, and shall be securely fastened to hanger support at the elevator pit floor and come up to the sills at floors above. Intermediate fastenings shall be made where necessary to ensure

against waves or buckling, and shall extend the full width of the opening plus 3 inches on each side of all entrances. Color of enamel finish shall be as selected from the manufacturer's standard colors.

H. Hanger Supports and Cover Plates: Hanger supports shall be 3/16 inch thick formed sections G. Fascia, Dust Cover, and Toe Guards: Fascia plates, dust covers and toe guards shall be constructed of not thinner than No. 14 U.S. gauge steel reinforced to insure flat even surface throughout, and shall be securely fastened to hanger support at the elevator pit floor and come up to the sills at floors above. Intermediate fastenings shall be made where necessary to ensure against waves or buckling, and shall extend the full width of the opening plus 3 inches on each side of all entrances. Color of enamel finish shall be as selected from the manufacturer's standard colors. securely bolted to struts. Cover plates shall be made of No. 14 U.S. gauge steel extending over the full travel of doors and shall be designed in removable sections to facilitate servicing hangers from within the elevator car.

I. Struts and Closer Angles: Structural steel angles shall be furnished of sufficient size to accommodate door closures. Angles shall be continuous and securely bolted to sills and building beams and concrete structure above.

J. Guards as required by Code for hoistway projections and recesses exceeding two (2) inches according to Code.

K. Finish of Steel: Except where encased in concrete, at edges or surfaces adjacent to edges to be field welded, all steel shall be given one coat of shop primer. Primer shall be as specified in Article 2.02.E of this Section. Primer coat shall be a minimum dry thickness of 2.0 mils. Top coat shall be applied to all primed coats of the car sling and frame, underside of car, struts and closer angles, guards, fascia, dust cover, and toe guards.

2.08 CAR EQUIPMENT

A. All hoistway equipment specified within this Article shall be designed and constructed with material and equipment of weatherproof classification.

B. Car Frame: Welded or bolted, rolled or formed steel channel construction. Isolate from jack unit.

C. Platform: Construct of steel and required framing members for the stainless steel floor application and shall be fireproofed on the underside.

D. Guide Shoes: Swivel with replaceable greaseless liners.

E. Car Sills: Extruded nickel silver.

F. Toe Guard: In accordance with Code.

G. Car Doors, Hangers and Tracks: Provide as specified for hoistway entrance doors, hangers and tracks.

H. Header: Construct of steel with shape to provide stiffening flanges.

I. Car Door Electrical Contact: Arrange so that elevator cannot operate unless doors are closed within tolerance allowed by Code.

J. Car Door Clutches: Heavy-duty clutches, linkage arms, drive blocks and pickup rollers or cams to provide positive, smooth, quiet door operation. Design clutches so car doors can be closed for maintenance purposes, while hoistway doors remain open.

K. Door Operator and Operation: Medium-speed, heavy-duty, DC master door operator capable of opening doors at no less than 1-1/2 f.p.s. Accomplishing reversal in no more than 2-1/2 inches of door movement. The operator shall open doors automatically when car arrives at a floor to permit egress of passengers. Close doors automatically after a timed interval in accordance with Code requirements. The operator shall be one specially made for the operation of glass hoistway and car doors so that no moving arms or mechanical parts passes in front of the door's glass panels. The operator shall be weather resistant.

L. Infrared Detector Device: Pulsed screen car door protective device projecting across entire entrance opening. Arrange controls to prevent elevator operation if device is not operative (excluding key operation switch in the service panel). The device shall be weather resistant and have diagnostic features.

M. Elevator Car Operating Panel (COP)

1. Elevator car operating panel (COP), NEMA 4X (Type 316) with a vandal resistant, illuminated, flush mounted faceplate consisting of a metal box containing the operating fixtures, mounted behind the stationary front return panel of the car enclosure. All control panel features shall be in accordance with ADA and MAAB physically challenged codes and standards.

   a. Two elevator control panels (main and auxiliary) for Elevator EV-1.

2. Floor buttons, alarm button, door open button and emergency stop keyswitch shall be identified by characters raised a minimum of 0.03 inch and 5/8 inches high. Characters shall be to the left of the buttons to which they correspond.

3. Floor buttons: The following designations shall be used for the level identification: for each elevator; S – STREET LEVEL, P – PLATFORM LEVEL. The levels served shall be identified by Braille character translations set adjacent to alphanumeric level designations. Car buttons shall align above each other in the order of floors served having the lowest floor served at the bottom. Locate operating controls between 35 inches and 48 inches above the car floor. The stop switch a, lowest floor at the bottom, alarm button shall be set 35 inches above the car floor. In all cases, the control sizes, labeling and heights shall conform to the ADA and MAAB physically challenged codes and standards. The emergency communication button shall be directly above the alarm button.

4. Provide 3/4 inch diameter metal pushbuttons raised 1/8 inch with concave scoop and which illuminate to indicate call registration.

5. Provide alarm button and emergency communication button at bottom of elevator car station to ring the bell located on the top or bottom of the elevator, and sound distress signal in the elevator supervisory panel in Room 103-Police.

6. Provide door open button to stop and reopen closing doors. Make button operable while car is stopped at a landing in accordance to Code.

7. Provide a lockable service panel with five sets of keys for the panel and all key switches within that shall be easily reproducible with a panel that is recessed, flush covers plate matching return panel.:

   a. Inspection switch, conforming to Code, for disconnecting automatic operation, limiting the car speed and activating hoistway access switch when car is at terminal landing.

   b. Light switch.

   c. Two-position exhaust blower switch.

   d. Independent service switch to permit selection of independent or automatic operation.

   e. Start button for closing doors and starting elevator when operating on independent service. (Floor pushbuttons may be used for this function.)

   f. Duplex 120 volt, AC, electrical convenience outlet.

   g. Test button for Emergency Lighting and Alarm.

      a. Security car lockout key switch (weatherproof) for the Street Level for EL #2.

   h. Inspection service key switch.

8. Control Key Switches outside of the service panel.

   a. Firefighter's Key Switch

   b. Emergency Stop (provide 5-sets of keys)

   c. Door Entry Security Key Switch (provide 5-sets of key)

9. Provide black paint filled recessed letters with size and style accepted by the Engineer as follows:

   a. Certificate of Inspection holder as required by Code and shall be #4 finish stainless steel (Type 316)..

   b. "No Smoking" on main car stations.

   c. Elevator capacity in pounds on car station.

10. Faceplate Material and Finish: #4 finish (Type 316) stainless steel.

11. Hands Free Intercom Communication (by others): The elevator emergency intercom communication shall be integral with the car operating panel (COP) and comply with the ADA Hands Free configuration requirements. The intercom button shall have the symbol of a telephone red in color with the white outline of the telephone or approved equal and be vandal resistant. This system shall be closely coordinated with Section 16750 for compatibility with its

system requirements and placement within the COP. The highest point of emergency communication device shall be 48 inches while the lowest point at 35 inches. It shall be identified by a raised symbol and lettering complying with 521 CMR 41, SIGNAGE, and located adjacent to the device. The emergency intercommunication system shall not require voice communication and shall have two (2) lights, one indicates that emergency contact has been made and the other indicating that the call is being responded to. The lights shall the message inscribed next to it.

N. Car Top Control Station: NEMA 4X, In accordance with Code. Control stations.

O. Emergency Exit: Exit shall be located in the car ceiling in accordance with Code and shall be located so it does not conflict with the low profile sling.

P. Work Light with guard and Duplex GFI Plug Receptacle: One of each at top and bottom of the elevator car. Provide lights with an on-off switch and bulb guard. Work light and duplex plug receptacle shall be weatherproof.

Q. Communication Systems

1. A complete intercommunication system for each elevator by the elevator manufacturer/installer shall be furnished and installed under this Section for the Elevator Intercom System. This system shall provide communication between the machine room and the COP. Provide the speaker and microphone within the COP with all wires and associated traveling cables. This system shall include a master station (NEMA 12) that is wall mounted by the controller and speaker/microphone (within the COP). The speaker/microphone must be separate from that provided in Section 16750.

   a. Remote stations within the car shall be vandal resistant. The remote stations shall be integral with the car control panel of each car.

   b. Speaker and microphone for 2-way communication.

2. All communication systems within the car station shall comply with ADA and MAAB (521 CMR) physically challenged codes and standards and the communication requirements between the top of car and remote machine rooms shall be in accordance with the State Elevator Code 524 CMR.

2.09 CAR ENCLOSURES

A. Observation Cars EV-1 and EV-2: See Contract Drawings and provide the following features:

1. Shell-Interior: Reinforced 14 U. S. gauge stainless steel with grain running horizontally. Apply sound-deadening mastic to exterior.

2. Shell-Exterior: Reinforced 14 U. S. gauge stainless steel #4 brushed finish with grain running horizontally. Apply sound-deadening mastic between exterior and interior panels.

3. Return Panels and Entrance Column: 14 U. S. gauge stainless steel with grain running horizontally. Integral with entrance columns, with cutout for car station operating panel, and with integral communication equipment, #4 brushed finish.

4. Base Cove and Transom: 12 U. S. gauge stainless steel, #4 brushed finish with grain running horizontally. Base shall be covered at floor and corners. Floor cove shall return vertically so that floor material shall meet cove in flush level joint.

   a. Base Cove: Cove shall return vertically (8-1/2 inches) so that the stainless steel floor shall meet the cove in a flush level joint at the base. Cove shall be mitered with no gaps.

5. Ceiling: Reinforced 12 U. S. gauge stainless steel with hinged exit operable from car top only. #4 brushed finish. Top of car cladding shall be stainless steel # 4 finish. Gauge shall be in accordance to Code to allow inspection maintenance personnel access.

6. Car Door and Hoistway Glass Door Panels: Door panels shall be 14 U. S. gauge, No. 4 finish stainless steel cladding on the exposed face. Car door panels shall have #4 brushed finish with 9/16 inch laminated glass according to Z97.1 standard in black neoprene gasket. Comply with requirements of weatherproof construction for EV-2.

7. Car interior heights shall be eight (8) feet.

8. Handrails at Front/Rear Entry Car (EV-1): 1 _ inches outside diameter stainless steel and wall connectors with #4 brushed finish at side walls. Handrail height is 34 inches above the car floor as indicated on the Drawings. Handrail placement on EV-2 shall be at the rear and sides.

9. Ventilation: 2-speed exhaust blower. Finish and material of fan enclosure and blade shall match the finish and material of the ceiling. Exhaust blowers shall be NEMA 4X and shall have an integral back-up battery per code requirements for observation cars.

10. Lighting - Vandal Resistant Fluorescent Fixture(s):

    a. Lights will consist of soffit lighting at each side, reinforced for vandal resistance.

11. Observation Windows: all glass shall be 9/16" thick laminated safety glass, complying with ANSI Z97.1 and 16 CFR.

12. Floor: The floor shall be _" thick (Type 316) checkered pattern.

13. Top of car handrail for EV-2 shall be stainless steel, No. 4 (Type 316), 3'-6" in height with intermediate horizontal. Vertical uprights shall be placed on a reinforced car top that allows proper bracing and support for handrail stability per Code requirements.

2.10 LANDING CONTROL STATIONS

A. Pushbuttons: Provide one riser flush mounted. Include vandal resistant, illuminated pushbuttons for each direction of travel, which illuminate to indicate call registration. Provide safety message, "In Case of Fire...", in pushbutton faceplate. Messages and symbols shall be recessed and filled with black paint in accordance with Code. Terminal floors shall have one button and intermediate floors two buttons.

1. Activation of the Door Entry Security system for EV-2 will make the designated entry at the Street Level landing inoperable. Manual key switch operation shall be in the hall landing placed a

minimum of three inches above the call button (weather resistant) and a security system for the car door shall be in the service cabinet of the COP.

2. Although the firefighters' key switch required by the State Elevator Code 524 CMR does not have a NEMA 4X rating, it will be used within the NEMA 4X fixture.

B. Hoistway Access Means: In accordance with Code. EV-2 key switch at Street Level shall be NEMA 4X (type 316).

1. Hoistway Access Switches shall be mounted in the entrance frame side jambs at terminal floors. Provide switch fixtures with faceplates in accordance with Code. Switches shall be the recoverable type with security screw attachments that does not require the door frame removal for switch replacement. All exterior hoistway access switches stations shall be a weather resistant type.

C. Firefighter's Key Switch: Install switches as designated in Article 2.01 ELEVATOR SCHEDULE. Faceplate shall have the recessed inscriptions as required by Code.

D. Faceplate Material and Finish

1. All faceplates to be NEMA 4X, Type 316, #4 brushed finish 14 U. S. gauge stainless steel.

2. Colors, symbols and signage pictograph identification shall be engraved.

E. At the designated main floor an emergency power override switch shall be provided per Code.

2.11 SIGNALS

A. Car Direction Lantern: Provide a vandal resistant, illuminated traveling lantern in the entrance strikepost which illuminates when the elevator arrives at that location and sounds an electronic tone, as the doors open, to indicate car direction. Tone shall sound once (higher pitch) for "up" direction and twice (lower pitch) for "down" direction.

B. Car Position Indicator: Provide a vandal resistant, illuminated horizontal fixture with letters and numerals representing the floor served centered over each entrance door. When a car leaves or passes a floor, illuminate individual letters and numerals representing the position of the car in the hoistway. The following designations shall be used for the level identification: S - Street Level, P - Platform Level.

C. Faceplate Material and Finish

1. Car Direction Indicators: Type 316, #4 brushed finish stainless steel.

2. Car Position Indicators: Type 316, #4 brushed finish stainless steel.

2.12 ELEVATOR SUPERVISORY PANEL

A. Supervisory Panel shall have engraved lettering, furnished and installed in Room 103-Police at the Platform Level. The supervisory panel shall be designed and coordinated for the supervisor's panel connection to the Station's emergency power transfer switch system and the elevator manufacturer shall provide any required transformers and hook-up to the 120 Volt power circuit. The panel shall be connected to the Programmable Logic Controllers (PLC) in the Communication Room. The panel shall consist of the following items wit a heading at the top of the panel "ELEVATOR SUPERVISORY PANEL" (1/2" height-1/8" stroke with other lettering _" height-1/16" stroke unless otherwise noted

1. A multi-light LED indicator recessed panel shall be installed at a location to be designated by the Engineer in Room 103-Police.

2. The panel shall contain illuminated indicators to provide the following information for the Elevators.

   a. The floor at which each elevator is currently located (Street or Platform).

   b. Which elevator is currently out of service.

   c. Operational program under which elevator is currently operating, such as: Firefighter's Keyed Switch Operation, Independent Service, Emergency Stop, Out of Service, Medical Emergency, Emergency Power

   d. Which car is activating the emergency communication with a blinking light (with buzzer for 5 seconds).

   e. Which car is activating the emergency alarm with a blinking light (with buzzer for 5 seconds).

   f. Activation of the security key switches for EV-2 hall and COP.

3. Each device in the panel shall be identified by 1/4 inch high recessed letters filled with paint contrasting to the color of the faceplate and organized in a manner that clearly illustrates all elevator positions and modes. The panel shall be constructed with minimal dimensions in reference to width, length and depth. Panel shall not exceed 12" in height and 18" in width.

4. Indicator faceplate shall be fabricated from not less than 1/8 inch thick painted steel with beveled edges and surface mounted.

5. Standby Power Operation: A standby power key switch shall be located at the bottom of the elevator supervisory panel centered below the engraved label STANDBY POWER OPERATION (1/2" height-1/8" stoke). The key switch shall have two positions, one labeled as AUTOMATIC and the other as EV-2 (1/4" height-1/16" stroke). Standby Power Operation will be set up to operate in this type of sequencing even if Add-Alternate No. 3 for EV-2 is not installed in this Contract, ready for hook-up at a later date by others.

   a. The key switch shall be a key type available to the MBTA staff, elevator maintenance and firefighters. When the key switch is in the "Automatic" position it automatically sends each elevaor to the designated main level in a consecutive manner starting with EV-1 and after both elevators have stopped and put out of service at the main level and went out of serve, EV-1 will automatically be selected for operation on full power providing all services after all

Firefighters' Phase I and II and Medical Emergency and emergency power override switches are in the off position.

b. When the key switch is turned to the second position labeled "EV-2" elevator EV-1 will come to gradual stop if traveling, reverse its direction if necessary and proceed to the main designated floor open its doors and shut down. If the elevator is at a landing, the doors will close with buzzer sounding in a door nudging mode. With the doors shut, it will travel to the main designated floor at Street Level, open its doors, and shut down allowing EV-2 to operate on full operation power.

c. The key shall not be removable only when in the "Automatic" position.

d. A commercial made sign made of plastic (white) shall be provided. The sign shall have _ inch caps saying STANDBY KEY SWITCH OPERATION in black letters having _ inch upper and lower case in black below it describing the key switch operation as listed above and shall be permanently mounted adjacent to the key switch.

2.13 STANDBY POWER OPERATION

A. All elevators shall be connected to the standby power and shall operate in a consecutive manner until each car is parked at the Designated Main Level then automatically taken out of service per ASME A17.1.1 and as modified by 524 CMR. See ELEVATOR SUPERVISORY PANEL above for operation requirements.

PART 3 - EXECUTION

3.01 SITE CONDITION INSPECTION

A. Prior to beginning installation of equipment, examine hoistway and machine room areas. Verify that no irregularities exist which affect execution of work specified.

B. Do not proceed with installation until work in place conforms to Contract requirements.

3.02 INSTALLATION

A. The Contractor shall correct all outstanding Department final punchlist items prior to scheduling the State Elevator Inspection unless otherwise directed by the Engineer. The Contractor shall coordinate all disciplines to ensure that Elevators EL #1 and #2 are fully operational, inspected, tested, re-inspected and re-tested when required to obtain the State's Elevator Operational License a minimum of one week prior to the Contract's scheduled opening of the Station for Public use.

B. Install each equipment item in accordance with manufacturer's direction, referenced codes, and the Contract Documents.

C. Install machine room equipment with clearances in accordance with referenced codes and the Contract Documents.

D. Install all elevator equipment so they may be easily removed for maintenance and repair.

E. Install all elevator equipment so that access for maintenance is safe and readily available.

F. Clean the following items of oil, grease, scale, and other foreign matter, and apply one coat of field-applied machinery enamel.

1. All exposed equipment and metal work installed as part of this work which does not have specified finish.

2. Machine room equipment.

3. Neatly touch up damaged factory painted surfaces with original paint and color. Protect machine-finish surfaces against corrosion.

3.03 INSTALLATION VERIFICATION

A. Prior to installation and acceptance tests in accordance with these Specifications, an installation verification shall be conducted by the Contractor to establish and verify the hardware against the Contract Drawings, Specifications, workmanship standards, and accepted elevator manufacturer's literature. Discrepancies identified by the Contractor or the Engineer shall be rectified by the Contractor.

3.04 FIELD QUALITY CONTROL

A. Work at the job site will be checked during the course of installation. Full cooperation with Engineer is mandatory. Accomplish corrective work required prior to performing further installation.

B. Have Code Official acceptance inspection performed and complete corrective work.

3.05 ADJUSTMENTS

A. Align guide rails vertically within the tolerances required by Code. Secure joints without gaps and file any irregularities to a smooth surface.

B. Balance cars to equalize pressure on guide shoes.

C. Lubricate all equipment in accordance with manufacturer's instructions.

D. Adjust equipment, including but not limited to, motors, pumps, valves, controllers, leveling switches, limit switches, stopping switches, door operators, interlocks and safety devices to achieve required performance levels.

E. Fabricate and assemble various parts in shop to minimize field assembly. Assemble parts which require close field fit in the shop and mark for field erection.

3.06 FINISH OF MATERIALS

A. Surface Prep: Clean all surfaces of oil, grease, scale, and other foreign matter in accordance with Steel Structure Painting Council Specification SSPC-SP-6 - Commercial Blast Cleaning.

B. Painting: All exposed surfaces of elevator car and equipment within the hoistway, excluding glazing, stainless steel and other factory finished items, shall be painted in accordance with the material standards in Article 2.02/E.

C. Field Repair Procedures: Where factory applied coatings have become damaged or abraded due to handling, transport, installation, welding or other circumstances, they shall be repaired by the Contractor.

1. All damaged areas shall be thoroughly wire brushed. All dirt, oil, grease or other contaminants shall be removed.

2. Touch-up paint shall be supplied by the factory, in identical color and composition to that used in the plant and shall be applied to all prepared surfaces to dry-film thickness of at least 3.0 mils.

3.07 CLEANUP

A. Keep work areas orderly and free from debris during progress of project. Remove packaging materials on a daily basis as equipment is installed.

B. Remove all loose materials and filings resulting from work.

C. Clean machine room equipment and floor of dirt, oil and grease.

D. Clean hoistways, cars, car enclosures, entrances, operating and signal fixtures, and trim of dirt, oil, grease, and finger marks.

3.08 ACCEPTANCE INSPECTION AND TESTS

A. General: Furnish labor, materials, and equipment necessary for tests. Notify Engineer 5 days in advance when ready for final review of each elevator unit or group. Final acceptance of installation will be made only after all field quality control reviews have been completed, identified deficiencies have been corrected (unless otherwise directed by the Engineer), all Submittals and certificates have been received, and the following items have been completed to the satisfaction the Engineer.

1. Workmanship and equipment shall comply with each specified and/or related Section.

2. Contract speed, capacity and floor-to-floor performance comply with the criteria within this Section.

3. Performance of following are satisfactory:

   a. Starting, accelerating, running

   b. Decelerating, stopping accuracy

   c. Door operation and closing force

   d. Equipment noise levels

   e. Signal fixture utility

   f. Overall ride quality

4. Test Results

a. In all test conditions, obtain specified speed, performance times floor accuracy without re-leveling, and ride quality to satisfaction of the Engineer.

b. Temperature rise in windings limited to 50 degrees Celsius above ambient. Conduct a full-capacity one-hour running test, stopping at each floor for 10 seconds in up and down directions, if equipment performance is questionable in Engineer's opinion.

B. Performance Guarantee: Should tests reveal defects, poor workmanship, variance or noncompliance with requirements of specified Codes and/or ordinances, or variance or noncompliance with the requirements of the specifications, complete corrective work at no cost:

1. Replace equipment that does not meet Code or Section requirements.

2. Perform work and furnish labor, materials and equipment necessary to meet specified operation and performance.

3. Perform and assume cost for retesting required by Engineer to verify specified operation and/or performance.

C. Field Review Scheduling: The Contractor shall schedule progress and final equipment reviews with the Engineer. The Contractor must reply promptly, in writing, to corrective work indicated on the Engineer's progress and final review reports, indicating status, schedule for completion, and questions. The Engineer anticipates that scheduled appointments will be met. Additional costs incurred by the Engineer for continued rescheduling and canceled appointment will be paid for by the Contractor.

3.09 INFORMATION

A. Provide six (6) sets of neatly bound written information necessary for proper maintenance and adjustment of equipment within 30 days following final acceptance. Final retention will be withheld until data is received and reviewed by the Engineer. Include the following as minimums:

1. Straight-line wiring diagram(s) of as-built elevator circuits, with index of location and function of components. Mount installation wiring diagrams on panels, racked, or similarly protected, in elevator machine room. Maintain with addition of all subsequent changes.

2. Lubricating instructions, including recommended grade of lubricants.

3. Parts catalogs for all replaceable parts including ordering forms and instructions.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

4.02 PAYMENT ITEMS

Item No.	Description	Unit
1420.000	ELEVATORS	LS

END OF SECTION

NOTE

1. **Attachment "A"** is entitled "Power Supply - Confirmation Data Form" from the National Elevator Industry Incorporated (NEII) 7th Edition of their publication entitled Vertical Transportation Standards, page 36. Attachment "A" includes two (2) page and is listed as page 33 of this Section and as modified for this Project.

ATTACHMENT A

POWER SUPPLY - CONFIRMATION DATA FORM
Type of Motor Controller: **Hydraulic Elevator**

Prepared By_____Date_____

Location, City _____Date_____

Building Name
Elevator Numbers: _____Job Number
MAIN ELEVATOR FEEDERS

_____VOLTS PHASE HERTZ_____

Voltage Tolerance + 5%, -10%. Frequency Tolerance ± 2%
Voltage Balance: Phase to Phase 5%. Phase to Neutral 5%.

CONDUCTORS
Electrical contractor to supply copper conductors and circuit protective devices from the building service to escalator control equipment, in compliance with ANSI/NFPA No. 70, National Electric Code with modifications by 537 CMR, State Electric Code and other local code requirements based on the electrical Elevator load data below.

ELECTRICAL DATA LOAD

Elevator Numbers	EV #1	EV #2 **Add-Alternate No. 3**	
Elevator Controller Nameplate (kw)			
Elevator Controller Nameplate (hp)			
Elevator Motor Starting Type			
Motor Starting Current (line acA)			
Rated Motor Current (line acA)			
Motor Code Letter			
Immersion Type Dipstick Heaters			
BRANCH CIRCUITS: GFCI protection (item 2) per NFPA No. 70, National Electric Code with modifications by 537 CMR, State Electric Code. 1. Lighting supply (120 Vac-1 Phase) with the following current ratings:			
Car Numbers			
Current (A)			
2. To each console panel 120 Vac, 15A-1 phase. APPLICABLE ELEVATORS:			

DISCONNECTING MEANS numbered, sized and located in accordance with NFPA No. 70, National Electric Code with modifications by 537 CMR, State Electric Code.

ADDITIONAL RECOMMENDATIONS: (To be noted by Elevator contractor)

CONFIRMATION APPROVAL: (To be used in conjunction with NEII Power Standards)

Electrical contractor/project engineer please confirm approve and return this data sheet.

Elevator Contractor (Title) Date

Electrical Contractor (Title) Date

END OF ATTACHMENT A

SECTION 14311

HEAVY-DUTY ESCALATORS

PART I GENERAL

1.01 GENERAL DESCRIPTION

A. This Section specifies the furnishing of all labor, materials, and equipment with experienced supervision for the delivery, assembly of four escalators (ES-1 through ES-4) and all systems and all incidentals, installation, system operation, testing and ready for use escalators as specified herein and in accordance with the Contract Documents.

B. During this Project modification to the Maverick Station, the Station will remain open during construction. The relationship of each Phase of construction phasing to its predecessor and successor stages is critical to maintain Station egress. Since the installation of each escalator in its scheduled Phase is critical to the construction schedule for pedestrian flow, the escalators must be fabricated, installed, obtain an operation certificate from DPS/EID and open to public in accordance with the Phase of construction as shown in the Contract Documents. The escalator Manufacturer/Installer is required to coordinate with the Contractor and complete the escalators within the Contractors scheduled time frame.

C. The existing KONE Heavy-Duty Escalator at the north Headhouse shall be removed and salvaged. The removal consists of the salvaging of the escalator truss, escalator status panel and system components as tagged by the MBTA and transported within a 50-mile radius of the Project Site to a point designated by the MBTA. Those items not tagged by the MBTA shall be removed from the site and disposed per the Contract Documents disposal requirements.

D. The work covered in this Section shall be coordinated and complimentary performed with the work of other trades included, but not limited to Article 1.02, Related Work Specified Elsewhere.

1.02 RELATED WORK SPECIFIED ELSEWHERE

A. The Contractor shall coordinate all disciplines indicated in Related Work to ensure that the new Escalators are tested, inspected and fully operational prior to the elevators opening for public use. Related Work includes, but is not limited to, the following:

1. DIVISION 1 – General Requirements
2. Section 02050 - Demolition
3. Section 03300 - Cast-in-Place Concrete
4. Section 03604 - Non-Shrink Construction Grout
5. Section 04200 - Unit Masonry
6. Section 05041 - Hot Dip Galvanizing
7. Section 05100 - Structural Steel
8. Section 05500 - Miscellaneous Metals.
9. Section 07101 - Waterproofing and Dampproofing
10. Section 07145 - Cementations Waterproofing
11. Section 07210 - Building Insulation
12. Section 07920 - Sealants and Caulking
13. Section 08800 - Glazing
11. Section 09900 - Painting
12. Section 10440 – Signage and Graphics
13. Section 15020 - Temporary Construction Ventilation
14. Section 15050 - Basic Materials and Methods for Mechanical Work
15. Section 15400 - Plumbing Systems
16. Section 15600 - Heating, Ventilation and Air Conditioning

17. Section 16050 - Basic Materials and Methods
18. Section 16120 - Wires and Cables
19. Section 16170 - Disconnects and Circuit Breakers
20. Section 16450 – Grounding
21. Section 16460 – Transformers
22. Section 16500 - Lighting
23. Section 16620 - Emergency Power Systems
24. Section 16682 - Elevator Intercom System
25. Section 16710 - Fire Alarm and Detection Systemection
26. Section 16770 - Public Address System

1.03 DEFINITIONS

A. Authority: Local jurisdiction Agency (DPS/EID) responsible for issuing certificates for use, inspections (including but not limited to the various agencies of the Department of Public Safety and the Boston Fire Department) and the MBTA witness for required testing.

B. Authority having Jurisdiction: The local organization, office, or individual responsible for approving equipment, an installation or component thereof, or a procedure. The jurisdiction Agency responsible for issuing the inspection certificate is the Department of Public Safety Elevator Inspection Department (DPS/EID), Boston Fire Department and the Project Representative for required inspections and testing.

C. Code: A citation of the codes, standards, publications and other references listed in Article 1.05 of this Section.

D. Complete Set: Shop Drawings shall be submitted as a complete set which includes, but not limited to all items in Article 1.09 SUBMITTALS and all other reference to submittal requirements within this Specification.

E. Contractor: The General Contractor for the specified Project. The General Contractor is responsible for all coordination between the various trades and associated Specification Sections for the escalator installation and operation. The General Contractor is also responsible for all his subcontractors to perform the work, tests and inspection as specified within this Section.

F. Device or a Part of the Equipment: Reference to a device or a part of the equipment applies to the number of devices or parts required to complete the installation.

G Dissimilar Metals: This specification terms metals dissimilar when two metal specimens are in contact or otherwise electrically connected to each other in a conductive solution and generate electric current.

H. Dynamic Brake Load: The minimum peak average load running in the down direction on exposed steps on the incline: 40 inch clear step width - 194 lbs. per step according to A17.1.

I. Escalator Manufacturer/Installer: The party selected under this Contract to furnish and to install the escalators as a subcontractor to the General Contractor under this Project/Contract. The phrase of Escalator Manufacturer/installer implies that the manufacturer is also the installer or the installer is approved by the escalator manufacturer for the installation of the escalators as specified within this Section.

J. Escalator Nomenclature: ASME A17.1, Safety Code for Elevators and Escalators, Appendix D, Escalator and Moving Walks Diagrams, Figure D3 for a Solid and Glass Balustrades.

K. Escalator Support: Includes the upper and lower pit face of support (FOS) and necessary intermediate supports.

L. Flat Steps: Number of flat steps shall be measured from edge of combplate in horizontal direction to first exposure of a riser, at upper and lower landings.

M. Galvanic Corrosion: Galvanic corrosion manifests itself in the accelerated corrosion caused to the more active metal (anode) of a dissimilar metal couple in an electrolyte solution or medium, and decreased corrosive effects on the less active metal (cathode), as compared to the corrosion of the individual metals, when not connected, in the same electrolyte component.

N. Heavy-duty escalator: An escalator designed specifically for transportation system usage.

O. Installer: Either the Escalator Manufacturer or an approved licensee of the manufacturer, who has not less than five years successful experience with the installation of escalators, and who is currently under contract for maintenance of escalators in the area, and who maintains a service center within 50 miles of the project site.

P. Letter of Certification: Submitted letter shall be notarized with requested compliance and signed by an officer of the Manufacturer/Installer as specified.

Q. MBTA: Massachusetts Bay Transportation Authority

R. Project Representative: This Project consists of representatives from the MBTA and their selected Project Representatives. Various submittals within this Section require review, decisions and information from these representatives that provide resultant review status of the subject submittal.

S. Periodic: The escalator system inspection, maintenance and testing shall occur at regular intervals. The intervals shall be according to established procedures set forth in the escalator maintenance manual for frequency, and never less than every month. The inspection, maintenance and testing frequency of the escalator system shall also conform to the ASME A17.1 and ASME A17.2.3 Codes description and intent for time duration between the referenced requirements.

T. Project Representative: This Project consists of representatives from the Architect and Engineers. Various submittals within this Section require review, decisions and information from these representatives that provide resultant review status of the subject submittal.

U. Routine: The habitual or mechanical performance of escalator system inspection, maintenance and testing shall be done according to established procedures of the escalator maintenance manual. The frequency of escalator system inspection, maintenance and testing shall not be less than every month. The inspection, maintenance and testing frequency of the escalator system shall also conform to the ASME A17.1 and ASME A17.2.3 Codes description and intent for time duration between the referenced requirements.

V. Slip Joints: A slip joint is a sliding joint required supporting escalators in high-rise applications. Location can be at top or bottom support areas but are generally located at the platform level or as required and indicated on the escalator shop drawings.

W. Special tools: Tools designed specifically for tasks associated with escalator examinations, maintenance, and repair, or those which are required for these tasks and are not readily available through normal purchasing channels.

X. Static Brake Load: The maximum accumulated load for the total number of exposed steps on the incline. The load per 40-inch clear step width shall be 194 lbs.

Y. Step Rated Load on Incline: The step rated load on incline for the step chain sizing and chain factor of safety based on the chain minimum ultimate tensile strength.

Z. Step Width: The horizontal distance between the skirt panels.

AA. Structural Rated Load: The load utilized in the truss deflection calculations and structural supports.

BB. System: Includes all escalator components, equipment, and incidentals specified within this section, unless otherwise used in context with a referenced system. The system is also inclusive of escalator components not specified in this Section but provided with the manufacturer's escalator operating system.

CC. Working points: Points of intersection of step nosing line and the horizontal line of the top and bottom landing plates at finish elevation.

1.04 TEMPORARY AND PERMANENT ELECTRICAL POWER SERVICES

A. Temporary power for installation shall be made available to Contractor at the time of the setting of truss. Permanent power shall be made available for testing. All power shall be provided at no cost to Contractor.

B. For the escalator drive systems: 480 volts, 3 phase, 3 wire, 60 Hertz terminating in a disconnect switch within sight of the controller.

C. For lighting and GFCI receptacles: 120 volts, 1 phase, 3 wire, 60 Hertz terminating in the escalator truss.

1.05 APPLICABLE CODES, STANDARDS, AND PUBLICATIONS

A. Escalator designs and installations shall be of the heavy duty, and shall comply with the Codes listed and referenced herein. The latest editions of codes, laws, standards and publications shall be used for all criteria listed within this Article and Section. Where there is conflict with the codes listed below or any portion of the Specification, the more stringent regulation and requirement shall govern. In all cases, Code shall be the governing factor except for ASME A17.1 in reference to these Section requirements that exceed Code and A17.2.3, A17.5 applicable edition. The local Code 524 CMR and its modifications noted therein is the governing Code. Any additional requirements imposed by local agencies shall be incorporated into escalator installations.

B. Acceptable Manufacturers: Fujitec America – Transit Model, KONE – ECO 3000, Schindler-9700, Thyssen-Krupp, Victoria or an approved equal by the MBTA.

C. Handicapped Accessibility Requirements: Massachusetts Architectural Access Board (521 CMR) and the Americans with Disabilities ACT (ADA).

D. The American Society of Mechanical Engineers (ASME) and the American National Standards Institute (ANSI) latest edition.

1. ASME/ANSI A17.1, "Safety Code for Elevators and Escalators"; except as modified by 524 CMR.

2. ASME/ANSI A17.2: Inspectors Manual for Elevators and Escalators.

3. Massachusetts State Building Code (latest edition)

4. ANSI Z97.1: American National Standard for Safety Glazing Materials Used in Buildings - Safety Performance Specifications and Methods of Test.

5. ASME/ANSI A17.5-M 1991/CAN/CSA-B44.1 Standard for Elevator and Escalator Electrical Equipment.

E. American Institute of Steel Construction (AISC)

1. AISC - Specification for the Design, Fabrication and Erection of Structural Steel for Buildings.

F. American Society for Testing and Materials (ASTM)

1. ASTM A36: Specification for Structural Steel.

2. ASTM A167 REV A-89: Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip.

3. ASTM A123: Galvanizing.

4. ASTM A325: Standard Specification for High Strength Bolts for Structural Steel Joints.

5. ASTM A446: Standard Specification for Steel Sheet, Zinc Coated (Galvanized) by the Hot-Dip Process, Structural (Physical) Quality.

6. ASTM A490: Standard Specification for Heat Treated Steel Structural Bolts, 150 kg Minimum Tensile Strength.

7. ASTM A500: Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.

8. ASTM A501: Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing.

9. ASTM B221: Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes.

10. ASTM C1048: Standard Specification for Heat Treated Flat Glass - King HS, Kind FT Coated and Unquoted Glass.

G. American Welding Society, Inc. (AWS)

1. AWS D1.1: Structural Welding Code Steel Twelfth Edition.

2. AWS A2.4: Standard Symbols for Welding, Brazing and Nondestructive Examination.

3. American Standard Booklet Z-49.1, Safety in welding and cutting provides recommendations for ventilation during cutting or welding of galvanized materials.

H. National Fire Protection Association (NFPA)

1. NFPA No. 51B, "Standards for Fire Prevention in Use of Cutting and Welding Process".

2. NFPA No. 70, National Electric Code with modifications by the governing Code.

3. NFPA No. 130, "Fixed Guideway Transit and Passenger Rail Systems"

I. Canadian Welding Society (CWS)

J. Canadian Standards Association, CSA B44

K. European Norm, EN115

L. ISO 281/I-1997

M. AFBMA, Std. 9 and 11

1.06 DESIGN CRITERIA

A. General

1. Escalators shall be designed with provisions for thermal expansion and contraction of complete escalator system assembly and for any movement of the facility caused by trains braking when fully loaded.

B. Operational Requirements

1. Hours of operation shall be considered as twenty-four (24) hours per day, seven (7) days per week
2. Direction of travel shall be considered as either direction, and unit shall be up and down reversible.
3. Rated Speed shall not exceed 90 feet per minute (FPM).- The no load to full load speed shall not exceed "4% of the rated speed

D. Structural Requirements

1. Contractor shall provide escalator truss mounting angles and intermediate truss supports with attachments, sized as required to install escalators into wellway structural support system shown on the contract drawing.
2. Escalator intermediate support points shall be provided by Contractor where required. Details and calculations shall be submitted by escalator Contractor for approval by the Authority.
3. Loads shall be indicated on contract drawings.
4. Loads were computed for heavy-duty, transportation system type escalators as described herein.

D. Environmental Requirements

1. General: Escalators shall be capable of operating with full-specified performance capability while exposed to the following climatic and environmental conditions. Escalators shall be designed to operate while indirectly exposed to the natural elements of weather and Station maintenance operations, including sunlight, rain, slush, snow and ice; all conditions of relative humidity while exposed to salt, de-icing chemicals, airborne dust, and debris, and corrosive elements; and in a drybulb temperature range of minus ten (10) to plus one hundred and five (+105) degrees Fahrenheit

2. Sound Level: Escalators shall be designed to operate at or below a sixty-five (65) decibels sound level, measured five (5) feet above the escalator at any location, with the escalator operating normally, either free running or under load. For multiple escalator installations, the noise measurements shall be made with only one (1) escalator unit in operation, but with the entire installation complete and in operating condition. An ambient level not to exceed forty-nine (49) decibels shall be maintained prior to units being turned on.

3. Fire Protection: Escalators shall be constructed of noncombustible materials as defined in ASTM A 136 throughout, with the exception of, handrails, handrail rollers, chain step wheels, and electrical equipment, Handrails shall have a flame spread rating of seventy-six (76) to two hundred (200), when tested in accordance with ASTM E 84.

4. Bearings shall be rated for an AFBMA L10 life as specified, under a fluctuating bearing load. All bearings shall have basic dynamic load ratings.

1.07 JOB CONDITIONS

A. Protection: During installations, and until escalator systems are fully operative, and inspected and approved for public use by DPS/EID, the contractor shall make necessary provisions to protect systems from damage, deterioration, and environmental conditions.

B. Coordination Requirements

1. Alterations: Contractor shall coordinate any alterations required to accommodate escalators with the Authority.
2. Cladding: Contractor shall review all appropriate contract drawings dealing with proposed methods of securing cladding to truss. Contractor shall coordinate with other appropriate contractors prior to any such actual work.
3. Floor finish at landing plates and newels: Contractor shall coordinate with other appropriate contractors and/or trades.
4. Escalator pit heating and ventilation: Contractor shall install heaters and ventilating fans where required.
5. Lock and key requirements: Contractor shall coordinate with the Authority.
6. Pit Drainage: Provide a means to prevent water from accumulating in the pit for outdoor escalators and indoor escalators subject to ground water or station wash downs.
7. Rigging Plan: Contractor shall supply a rigging plan that is approved by the Authority.
8. Safety Training: Contractor shall attend appropriate safety training programs provided by the Authority at no extra cost.
9. As built drawings: Contractor is responsible to provide revised contract drawings to reflect the actual as built condition including all structural, architectural, electrical, mechanical and plumbing connections to the escalators.
10. Methodology: The contractor shall meet with the Authority and provide a written method of installation for approval.

1.08 QUALITY ASSURANCE

A. Regulatory agencies: escalator design, materials, construction clearances, workmanship, and tests shall conform to the requirements of the codes and regulations listed in part 1.04, APPLICABLE CODES, STANDARDS, AND PUBLICATIONS.

B. Welding: Welding shall be performed in accordance with the requirements of AWS or CWB Welders shall produce evidence of current certification by AWS or CWB.

C. Dimensions

1. Each escalator shall be forty (40) inch (1000mm), nominal step width as specified and designed for a maximum of 30 degrees.
2. Structural dimension requirements:
   a. Contractor shall design and fabricate escalators to fit within the designed structures as shown on the Contract Drawings.
   b. Contractor shall verify dimensions of wellways prior to manufacturing trusses.
3. In the event of a discrepancy, Contractor shall notify the Authority immediately, and shall not proceed with installation in the areas of discrepancy, until the discrepancy has been fully resolved, and the Authority has instructed Contractor to proceed. Failure of Contractor to report discrepancies shall constitute an acceptance of existing work as fit and proper for the execution and completion of Contractor's work.

D. Labeling: Every escalator shall be clearly marked permanently on the controller with rated load and speed, braking torque, manufacture serial number, and the designated Authority identification and the required Code Data Plate.

E. Requirements of Regulatory Agencies

1. Contractor shall obtain and pay for all necessary permits, and perform such tests as may be required for acceptance and approval of escalators by jurisdictional agencies.
2. Contractor shall notify the proper inspectors to witness required testing.

F. Factory Visit

1. The Contractor shall provide for the costs of up to three of the owner=s representatives to visit the factory where the escalator is being manufactured.
2. The escalator shall be tested with the controller to be shipped with the escalator. The Owner and/or his authorized representative(s) shall observe the steps and step chain in operation and to test selected devices.
3. The Contractor shall not ship the escalator without the approval of the owner and/or his authorized representative(s) after the conclusion of the factory visit.

1.09 SUBMITALS

A. Shop drawings: Six (6) copies of the shop drawings shall be provided by the Contractor for approval within three weeks of notice to proceed. Drawings shall include, but not be limited to, facsimile outline of escalator truss in profile and plan; facsimile elevation of escalator balustrade, and vertical section through balustrade and truss midway between working points. All bearing ratings, identification and catalog numbers shall be provided

B. Record drawings shall be submitted for the following: Drawings shall show truss stanchion; track system and supports; drive system; step nosing radius at upper and lower ends; drive chains and gear train; step chain or step links (including chain pitch, step, and trailer wheels); step assembly (including axle, step tread, frame, and riser); handrail system (including profile, guides, drive, and tension device); support details (including upper, lower, intermediate, and slip joint), balustrade high-deck cover, interior panels, skirt panels, and their moldings; safety switches and operating devices; motor and emergency brakes; floor plates; speed governor; metal gauges; radial, vertical, and horizontal dimensions required for manufacture, and positions of lower and upper working points; attachment of truss to structure; major mechanical and electrical components within truss; drainage and electrical interfaces; hand and finger guards; ceiling intersection guards; passenger instruction signs; emergency stop button; and operating panel in upper and lower balustrades (including stop button, start and direction selection switches, and fault finder receptacle). In addition, a complete schematic diagram shall be provided for the controller and all electrical devices. The Contractor is not relieved of his obligation to meet the specifications. If the record drawings do not comply with specifications, the Contractor shall immediately remedy the condition in the field and update record drawing accordingly.

C. Maintenance programs: within sixty (60) days after notice to proceed, and prior to installation, contractor shall submit detailed interim and revenue service maintenance programs, showing functions to be performed and their scheduled frequency.

D. Operating and Maintenance manuals: Prior to installation, contractor shall submit six (6) complete sets of Operation and Maintenance manuals for approval: After Authority approval and prior to the beginning of acceptance testing, six (6) sets of the approved manuals shall be provided by the contractor. The manuals shall include the following:

1. Complete table of contents.

2. Complete instructions regarding operation and maintenance of equipment, including disassembly and assembly of drive system, handrail drive assembly, and track system. Included will be complete illustrated, exploded views of all assemblies, and a complete, illustrated, exploded view for identifying all system parts.
3. Complete nomenclature of replaceable parts, part numbers, current cost, and warehouse location. If product source is another vendor, contractor shall include name and address of other vendor.
4. Sample copies of a preventive maintenance chart.
5. Descriptions of safety devices listing and describing each fault code number in the diagnostic system.
6. Safety rules, tests, and procedures, including testing of all systems and subsystems.
7. Procedures for adjusting brake, handrail tension, handrail chain drive tension, step chain tension, track system, and mechanical components, including pictorials.
8. Instructions for removing floor plate, interior and exterior balustrades, replacing comb segments, and removing and installing steps, and interior panels.
9. Troubleshooting techniques.
10. Detailed lubrication and cleaning schedule indicating weekly, monthly, quarterly, semiannual, and annual lubrication; and a description of each lubrication point, lubrication type, and specification.
11. Control and schematic electrical wiring diagrams of controller, including wiring of safety devices to connections with remote indication and control panels for each escalator and group of escalators.
12. Electrical layout showing placement of lighting, light switches, receptacles, light fixtures, disconnect switches, and convenience outlets in machinery room, truss envelope, and pits.
13. Complete detailed drawings and wiring diagram of escalator fault-finding device and connection to annunciator panel.

E. Certification:

1. The escalator manufacturer shall provide to the owner, certification, that the owner of the escalator(s) shall be provided with copies of all documents related to maintenance, safety, operations, design changes, modifications, retrofits, etc., Which relate to any part, component, equipment, system, subsystem, or material and services applicable to the escalator provided.
2. All of the above referenced shall be provided as it pertains to the original installation and for a period of ten (10) years after final acceptance of the last escalator provided under any contract.
3. The referenced material shall be provided within thirty (30) days of publication or internal distribution by the escalator manufacturer. The material, even if labeled PROPRIETARY, shall be delivered to the Authority without prejudice or delay and at no additional cost.
4. Provide all material on CD-ROM in a format approved by the Authority.

F. MSDS and product data sheets: Shall be submitted with an index listing each product, along with the application method of the product, approximate quantity of product per escalator, and the component the product is applied to or associated with. The contractor shall allow 6 (six) weeks for review of MSDS.

PART 2 PRODUCTS

2.01 GENERAL REQUIREMENTS:

A. Contractor shall furnish and install escalators that shall comply with the following requirements:

1. All escalators supplied under this contract shall be the product of a single manufacturer.

B. Escalators shall comply with the following requirements:

1.	Vertical Rise	As Shown On Contract Drawings
2.	Inclination	30 Degrees
3.	Nominal Step Width	1000mm (40 in.)
4.	Speed	not to exceed 90 FPM
5.	Flat Steps	3 minimum at top and bottom landings
6.	Maintenance Speed	No greater than 25% of rated speed.
7.	Upper track radius	Minimum of 10m: 2.6m (8' 6 ")
8.	Lower track radius	Minimum of 2.0m (6' 6 _")

9. Static Brake Load: The load per step the total number of exposed steps on the incline.
   a. 1000mm step: 306 kg (674lbs)
10. Dynamic Brake Load: The load per step running in down direction on exposed steps on the incline:
   a. 1000mm step: 145 kg (320lbs)
11. Motor Duty Load: Continuous operations with a minimum step load per step (on incline only) as follows:
   a. 1000mm step: 145 kg (320lbs)
   b. 800mm step: 116 kg (256lbs)
12. Step Chain Load: is to be based on the step loads as follows:
   a. 1000mm step: 145 kg (320lbs)
   b. 800mm step: 116 kg (256lbs)

C. Controls and Safety Devices

1. Operating controls:
   a. Escalators shall have key operated switches, accessible at both upper and lower landings, located on the exterior high-deck above the newel base. Alternate locations may be used subject to approval by the Authority.
   b. Each keyed switch shall be clearly and permanently labeled, including starting and direction selection.
   c. Interlocks shall be provided to bring the escalator to a smooth stop, in either direction of travel, before a change of direction may be made.
2. Safety Devices:
   a. Safety devices include, but are not limited to those, which are required by the edition of ASME A17.1 in effect as modified by 524 CMR for this installation.
   b. A lockable stop switch or disconnect shall be provided in both pits of escalators.
3. A fault-finding device shall be provided in the newels, capable of producing indications of the following data:
   a. Date, time, and cause of escalator stoppages.
   b. The fault indication shall remain visible until reset by an authorized person.

D. Balustrades, Skirt Panels and Decking

1. Balustrades and skirt panels:

a. Panels shall be a minimum of 3mm solid type 316 stainless steel. Backing panels, where used, shall be noncombustible, and subject to Authority approval.
b. Panels shall be constructed, when practical, in equal lengths for interchangeability.
c. Panels shall be attached to permit easy removal for inspection, lubrication, and adjustment of safety devices.
d. Panels shall be sized so that not more than two (2) persons shall be required to remove a panel, and without the aid of special handling equipment.
e. Exposed panel fastener requirements (where used): panels shall be fastened to their respective supports or mating portions with tamper-proof, flathead machine screws.
f. When framework to which panels are fastened is less than one quarter (1/4) of an inch thick, steel backup plates with a minimum one quarter (1/4) of an inch thickness shall be added which have tapped holes or clearance holes where necessary.

2. Decking shall be stainless steel, identical to balustrade, with minimum of 2mm.
3. High-decking between escalators shall be designed to support a live load of one hundred and seventy-five (175) pounds per square foot, without permanent deformation. High-decking at escalator sides shall be extended as shown on the architectural drawings and support the live load as specified for the common decking between escalators.
4. Paneling, decking, and other enclosures shall be supported on steel frame.

E. Electrical Equipment

1. Motors: The driving motors shall be AC induction motors with starters. Voltage 480 V.A.C., 3 phase, Frequency 60 Hertz.
   a. The motors shall be totally enclosed with external cooling fins.
   b. The motor protection class shall be equivalent to. IP 55 Insulation group: F
   c. Driving motors and motor switchgear shall provide a smooth start.
   d. The motor shall be designed for continuous operation(s) under a load as follows:
      1) 1000m wide step, 145 kg Per step on the incline. .

2. Controller
   a. The escalator control equipment shall contain diagnostic capabilities as required for the ease of complete maintenance. The diagnostic system shall be an integral part of the controller and provide user-friendly interaction between the service person and the controls. All such systems shall be free from decaying circuits that must be periodically reprogrammed by the manufacturer.
   b. Switch gear shall be mounted in NEMA 4X cabinets with strip heaters and labeled terminal strips.
   c. The main controller shall use an Allen Bradley SLC5/03 Programmable Logic Controller (PLC) or approved equal, to control and monitor the status of the escalator. The PLC shall be designed with all necessary hardware and software to communicate over Ethernet or approved equal.
   d. The PLC racks shall provide space for two (2) future single slot modules.
   e. The PLC in the remote control panel shall also have hardware and firmware provisions to communicate with interactive operator interface (monitor).
   f. The PLC shall store as a minimum, the last 99 faults, accessible via laptop connection, panel view or remote communications.
   g. Provide a copy of all working programs on approved computer medium as well as a printed program listing.
   h. The Programmable Controller shall have one dedicated serial port, which supports RS-232-C signals. It shall be accessible in ladder logic and provide support for Point to Point and Slave SCADA communication protocol systems.

Alternatively, it must be usable for programming purposes or for access to remote programmers via modems.

i. The controller shall be connected to the Escalator Status Panel will all necessary transformers and wiring hook-ups for operation.

3. The main control switchgear of an escalator shall contain at least the following devices:
   a. Lockable main switch thermal and magnetic motor protection starter for up and down travel, hour counter, auxiliary contactors, phase failure device, phase sequence monitor, and ground fault monitor.
   b. The controller cabinet shall contain a permanently mounted fault indicator board with indicator lights. Each group of safety devices shall be connected to one (1) signal lamp.
   c. The indication shall be locked automatically. Reset shall be done by a separate switch installed in the controller. The emergency stop shall not be locked.
   d. All terminals shall have identification markings and all cables shall be provided with cable markers.
   e. The controller shall be equipped with an AC induction motor reduced voltage starter; installed in line between the standard type contactor and the drive motor. The starter shall be solid state, capable of starting motors smoothly and gradually, reducing inrush current and mechanical shock upon start up. Adjustable settings for accelerating time and starting torque shall be provided. The starter shall also contain auxiliary contacts and a thermal overload relay for motor protection.
   f. Maintenance Receptacles: Electric power receptacles shall be furnished and installed in the upper and lower pits. Each receptacle shall be of the GFCI duplex type, waterproof, grounded, and rated for one hundred and twenty (120) volts at twenty (20) amperes. The receptacles in the pits shall be surface mounted on the walls, not less than thirty (30) inches from the floor.
   g. Relays shall be provided with visual indication that they are energized.
   h. Adjustable settings for accelerating time and starting torque shall be provided. The starter shall also contain auxiliary contacts and a thermal overload relay for motor protection.

F. Maintenance Drive Unit: Means shall be provided for reduced speed maintenance operation that shall be controlled by a manual handset. When operated, the escalator shall run in the direction selected, at a speed of not more than 25% of rated speed. This speed shall be maintained when steps are removed for servicing. Escalator operation shall be continuous so long as an up or down button on the handset is being pressed. The handset shall have a ten (10) foot retractable type cord with a plug connector. When plugged into receptacle, there shall be no means of operating or running the escalator except by the service handset. Receptacles shall be located in both the upper and lower pits.

2.02 MATERIALS

A. Stainless Steel
   1. Shapes and bars: ASTM A-276, type 316, A-554 for tubes.
   2. Plate, sheet, and strip
      a. Over one eighth (1/8) of an inch:-ASTM A-240-Type 316.
      b. Under one eighth (1/8) of an inch: ASTM A-240, Type 316.

B. Fasteners
   1. Fasteners shall be compatible with materials being fastened fasteners shall be furnished with self locking nuts or retaining rings (spring washers, toothed disks).
   2. Fasteners shall be equal to or of greater corrosion resistance than the most corrosion resistant metals being fastened.

2.03 FINISHES

A. Stainless Steel: No. 4 finish ASTM A-480

B. Aluminum Castings and Extrusions: Commercial mill finish:

C. Galvanizing

1. Sheet Steel: ASTM A446, or A526, as applicable. Coating designation G185.
2. Other galvanizing ASTM A123, AS1M A 153, ASTM A 385, or ASTM A 386, as applicable.

D. Galvanizing Touch up: Zinc dust coating, MIL-P-21035 or MIL-P-26915.

E. Paint and Corrosion Protection Each escalator shall have the following minimum corrosion protection.

1. After welding, the truss shall be hot dipped galvanized with a coating in accordance with ASTM A90. A 100% zinc thermal spray coating to ASNI/AWS C.18-93 is an acceptable alternative.
2. Cast metal parts such as gear housings, chain sprockets and return station half circles, shall be painted with a rust inhibitive primer coat after preparation by sandblasting.
3. Steel parts, which are not specified to be galvanized, shall be painted as follows:
   a. Primer coat two (2) mil (dry film thickness), minimum thickness.
   b. Second finish coat two (2) mil (dry film thickness), minimum thickness.
4. Bright or uncoated axles, shafts, etc. Shall be protected by zinc chromate, or chrome plating.
5. Oil collector chutes and collection trays shall be fabricated of galvanized steel.

2.04 MECHANICAL EQUIPMENT

A. Tracks

1. Fabrication of tracks shall retain steps and running gear safely under load requirements and at the highest speed specified
2. Contractor shall assemble and secure sections of track together for easy removal and replacement of defective sections. The system shall be adjustable, and welding of the track sections is not acceptable.
3. Design of the mechanical components shall provide for easy installation and removal without the dismantling of parts of the structure.
4. Tracks shall be properly supported on trusses to provide correct alignment and smooth transition to return stations. The rolling surface of the track shall be a minimum thickness of 3mm.
5. The guiding system for the step chains and step wheels shall be of zinc plated or galvanized steel profiles with smooth and even running surfaces, and with the joints cut diagonally to the running direction. The guide profiles shall not be welded together at the joints.
6. A second, continuous guiding profile shall be provided above the step chain rollers so that the step chains are positively guided in the area of the escalator open to passengers.

B. Steps

1. The step to skirt gap shall comply with the requirements of ASME A17.1-d 2000 regardless of any previous version of ASME A17.1 in effect.

2. The entire step assembly shall be unpainted natural aluminum finish or treated with not less than one (1) coat of zinc chromate primer or iron phosphate and one (1) coat of powder coated enamel for corrosion resistance.
3. Warning Edge: Step demarcation warning edge shall be provided for each step noising and edges in widths and materials that comply with all applicable laws and Codes. Material selection shall be a product routinely used for this specific application within the escalator industry.
4. Steps and their various attachments shall permit removal of steps without disturbing balustrades.
5. The design shall permit the running of the drive without steps for convenience in cleaning and inspection.
6. Step rollers shall have polyurethane tires on hubs, sealed roller bearings, and a diameter of no less than four (4) inches. Step rollers shall not require any additional lubrication and must be rated for severe, heavy-duty service.
7. Steps shall be constructed to be driven by step linkages to step or step rollers.
8. Washers and nuts shall be provided as follows:
   a. Tap bolts: Lock washers
   b. Through bolts: Lock nuts or Authority approved equal
9. Rated Loads:
   a. In addition to the minimum requirements given in the Codes, Contractor shall design the Steps for a minimum load of six hundred and fifty (650) lbs. (1430 Kg) per forty (40) Inch
   b. The steps shall carry the load under maximum concentric and eccentric loading conditions without distortion.
   c. Contractor shall perform dynamic testing, witnessed by Authority representatives if requested, at the Contractor's expense to verify the structural strength and serviceability requirements.

C. Step Chain

1. Chain shall be endless, roller type step chains; one (1) on each side of step.
2. Step chains shall be of heat-treated steel construction, supported at intervals by linkage wheels.
3. A means to prevent steps from coming into physical contact with each other and to prevent chains from sagging or buckling shall be provided
4. A means to maintain constant distance between step axles shall be provided.
5. An automatic tensioning device to maintain tension under load and to compensate for wear shall be provided. The device shall be located within the truss at the lower end.
6. A means for individual fine adjustment of tension for each linkage shall be provided
7. Step chains shall be constructed to permit removal of segments as may be required for replacement purposes at a minimum of every 6 axle section. Each escalator shall have at least two one axle sections.
8. Support wheels spaced to distribute load and to guide linkage throughout run shall be provided Rollers shall be constructed of polyurethane material, with diameter sufficient to provide reliability, maintainability, smoothness of motion, and to operate within noise level requirements specified The chain rollers shall have polyurethane tires on metallic hubs, sealed bearings, a diameter of not less than four (4) inches, must require no additional lubrication, and be mounted outside the chain link
9. Wheels shall be affixed to permit rapid replacement.
10. Each pair of step chains shall be a matched set within manufacturing tolerances. Only precision, rollerfishplate chains of high-grade heat-treated steel shall be used as step chains. The pins, axles, bushing, and rollers shall be hardened and ground.
11. Step chain and chain pins shall have a minimal diameter of at least five-eighths (5/8) of an inch. In addition, the diameter will be of a size so that the surface pressure at engaging points will not exceed 20N/m_

(2,900 p.s.i.). This is to be based on the step loads as follows:
   a. 1000mm wide step 145kg (320 lbs.) Per step on the incline.
   b. 600mm wide step 116kg (256 lbs.) Per step on the incline.
12. The safety factor shall be 6.
13. A test certificate for the chain breaking load shall be provided.
14. A shielding device shall be provided to protect chain, track guides, and rollers against water, dirt, and debris.

D. Combplate Assemblies

1. Complete assemblies of wear resisting, non-corrosive metal material, with exposed anti slip surfaces shall be fabricated.
2. Combplate sections meeting the following requirements shall be provided
   a. Shall be removable to permit ease of replacement.
   b. Shall be yellow in color for safety/demarcation.
   c. Shall have not less than three (3), nor more than seven (7), combplate sections per Combplate assembly.
   d. Provisions for lateral and vertical fine adjustments shall be provided so that cleats of step treads pass between combteeth with minimum clearances.
   e. Combteeth meeting the following requirements shall be provided
   f. Teeth shall be designed to withstand a load of two hundred and fifty (250) pounds applied in an upward direction at the tip of any one (1) tooth.

E. Floor Plates

1. Shall have 316 stainless steel frames at floor openings, designed to be supported on truss heads.
2. Shall be designed to cover entire area of upper and lower landings as indicated.
3. Shall be reinforced, as necessary, to be rigid and able to withstand a live load of two hundred and fifty (250) pounds per square foot with zero permanent deformation.
4. Shall be extruded of die cast aluminum in a ribbed pattern transverse to the escalator axis. Ribs shall be designed to provide maximum traction, and will be finished in the same manner as the combplates.
5. Shall have exposed portions constructed of material and finish to harmonize with steps and combplates.

F. Drive Machinery

1. Motor and drive mechanism shall be mounted within the truss envelope and step bank at the upper end. Shafts shall be designed for ease of assembly or disassembly.
2. Gear Box Requirements:
   a. Gear bearings shall be rated with an AFBMA L10 life of 200,000 hours and housed in an oil tight, dust proof case provided with a sight glass or dipstick method of determining oil level in the case. The case shall provide a convenient method of draining the oil.
   b. Use synthetic lubricants, subject to Authority approval, are used.
   c. The assembly shall have no openings in order to minimize accumulation of dust and debris.
   d. Rotating parts shall be provided with a means for lubrication and retention of lubricants.
   e. Sealed bearings shall be used in those environmental conditions where entry of water or dust may adversely affect bearing performance.
   f. Exposed, moving, drive elements shall be protected by sealed metal housings, which shall provide continuous lubrication to components.

g. Provide a low oil sensor to prohibit starting of the escalator on automatic operation with low oil in the gearcase.

4. V-belt and tooth belt drives shall not be considered acceptable. If chain drives are used, they shall be protected against dirt and water by sealed housings, and shall have an automatic lubricating device and a means of taking up any slack in the chain.

5. Main drive bearings shall be rated for AFBMA L10, 200,000 hours.

G. Drip Pans

1. Galvanized, 3mm steel, water tight drip pans for the entire length and width of trusses shall be provided. They shall also be sloped for proper drainage and collection of spent lubricants as well as any moisture or water which may enter the escalator. They shall be constructed to prevent oil from leaking below the truss.

2. Drip pans of sufficient size to collect and maintain, within truss areas, oil and grease drippings from step linkage and all forms of loose debris that maybe deposited in drip pans from steps at turn around points at upper and lower portions of truss shall be provided. This system shall be separate from the water drain in order to prevent the discharge of spent lubricants into sewer system.

3. Access to drip pans at lower landings of escalators for the purpose of cleaning drain catch basins shall be provided.

H. Handrails

1. General

a. Handrails shall receive their motion from main escalator drive through direct gearing and drive shaft or drive chains, so that handrail and steps operate at the same speed in each direction of travel. Driving and guiding wheels shall have a groove to accept the wedge on the underside of the handrail.

b. A means to take up handrail slack using a tensioning device, where required, shall be located within escalators. In addition, an approved method of releasing the device for repair or removal of handrails shall be provided pre tensioning of handrail shall be considered unacceptable.

c. Newels meeting the following requirements shall be provided:

1) Newels shall be designed and constructed so that handrail shall return into newel end at a point inconspicuous and difficult for passengers to reach

2) Newel sheaves shall be provided at upper and lower newels.

3) Handrails, handrail drive system, and guides shall be so designed and installed that handrail cannot be thrown off or disengaged while running, and special design attention shall be given to area where handrail passes from drive system to guides.

4) Handrail rollers shall have sealed bearings rated at AFBMA L10, 100,000 hours and have provision for retention of lubricant to ensure satisfactory lubrication and operation. Additional lubrication shall not be required.

5) Friction drive sheaves and idlers shall be designed and positioned so that lubricant cannot reach surface of handrail. Marking and spotting of handrail by drive equipment shall not be permitted. Provide sealed bearings rated at AFBMA L10, 100,000 hours.

6) Handrails shall be constructed of laminated, steel, wire mesh, or steel cable reinforced, flexible elastomeric material vulcanized into an integral, seamless, smooth handrail resistant to environmental conditions. A V-shaped underside design shall be used, providing a more positive drive.

7) Handrail color shall be black.

8) Handrail guides shall be continuous on exposed portion of handrails, constructed of 316 stainless steel which shall not subject to corrosion nor pitting, and shall have a polished or specially coated, permanent finish to minimize frictional wear to under surface of handrail. On the unexposed portion, guiding shall be by adjustable rollers having sealed bearings, and set in a way so as not to cause wear on the handrail.

9) Provide synthetic slider material.

10) Handrail gearbox, if provided, shall have bearings rated at AFBMA L10, 200,000 hours.

I. Braking Requirements

1. Motor Brake
   a. Brake shall be capable of stopping and holding a descending escalator with a load on the exposed steps in the incline area of:
      1) 1000mm wide step 145kg (320 lbs.) Per step
      2) 600mm wide step 116kg (256 lbs.) Per step
   b. The brake coil shall be insulated to class F.
   c. A monitor shall be provided, and if brake lining becomes insufficient for safe usage, restart of escalator shall be prevented.
2. Step Band Lock
   a. Shall be manually applied and mechanically engaged to prevent movement of linkages, while escalator is disconnected from its power supply.
   b. Electrical interlock that shall prevent escalator drive motors from starting while step band lock is engaged shall be provided.

J. Trusses

1. General:
   a. The deflection of the loaded truss shall not exceed one thousandth (1/1000) of the free supporting distance of not less than fifty (50) feet under full static load including live load as of 320 pounds per 40 inch step and 256 pounds per 32 inch step.
   b. The slip joint slide bearings shall not use grease for lubrication.
   c. Provide a permanent identification on the truss for the centerline at both ends of the escalator and in both transition curves.
2. Field Splices, Connections and Shims
   a. Field splices for ES-3 & 4 are required while ES-1 & 2 is dependant on construction phasing by the Contractor. The truss shall be rigid, non-deforming, and shall maintain alignment.
   b. Field modification shall not compromise the paint and corrosion protection specified in section 2.03.B.
   c. Shims shall be 316 stainless steel with a maximum shim height of 2 inches.
   d. The middle truss sections at its bottom shall have a clip angle attached so it can support a 16-gauge guard (by others) that spans horizontally between the truss sections.

K. Step Chain Tensioning Device

1. The step chain tensioning device shall be of a design that keeps the step chains at the correct tension.
2. A pointer and scale shall be provided to gauge step chain tensioning and wear.
3. Bearings: If used, shall be rated: AFBMA L10, 200,000.

L. Lubrication System Requirements

1. Step Chain:
   a. All parts, other than sealed items, requiring lubrication shall be designed for an automatic or remote lubricating system, The system shall operate only when escalator is running and the amount of lubrication shall be fully adjustable. A reservoir with a low oil signal to the controller, and a minimum capacity of two and one half (21/2) gallons shall be provided.
   b. System shall be positive acting, located in escalator pit.
   c. Reservoir level indications shall be provided where lubricants are contained within housings, supply tanks and larger filler cups.
   d. Electric heaters installed and connected to panel shall be employed to maintain lubricant viscosity where required.
2. Miscellaneous Lubrication:
   a. Contractor shall furnish and mount-on the controller cabinet, a laminated-lubrication chart for each escalator. The chart shall show the location of each lubrication point, type of lubricant to be used, and the frequency of lubrication.
   b. Bearings
      1) Sealed bearings shall be used where possible.
      2) Bearings requiring manual lubrication shall be furnished with fittings to accommodate the use of a pressure gun for lubrication.
      3) Self lubricating bearings or material other than ball or roller type bearings may be used where practical.
3. Manual Lubrication
   a. Location of manual lubrication points shall be easily accessible and available.

M. Indicators

1. Escalator users shall be informed by means of indicator lights of the predetermined running direction of the escalator.
2. Two (2) circular cut outs, minimum diameter two and three quarter (2 _") inches. Shall be provided in the upper and lower right hand balustrade newels, each containing an inset red and green light. The green light shall be illuminated at the entrance for escalator running direction and the red lamp shall have a horizontal white stripe and shall be illuminated at the exiting end. No incandescent lamps shall be permitted.

N. Room Storage Cabinet (Optional)

1. A metal cabinet of not less than twenty (20) cubic feet in volume (52 inches high x 36 inches wide x 18 inches deep) shall be provided in a room assigned by the Authority.
2. Cabinet shall have lockable doors and be mounted on legs or a pedestal, a minimum of four (4) inches off the floor.
3. Cabinet shall be painted and marked for control purposes, as directed by the Authority, and Contractor shall store small parts, supplies, tools and other materials within.

O. Lock Cylinders

1. All locks and keys shall be as per Authority approval.
   a. Authority shall verify with the Contractor that the requirements for hardware have not been amended or superseded
   b. Contractor shall provide the Authority with length, finish, and camming requirements of each cylinder required.

P. Demarcation Lights

1. Shall be U.L. labeled suitable for wet locations.

Q. Safety Brushes: Apply safety skirt brushes the entire length, both sides at the skirt panels from the upper to lower combplates. The MBTA standard for safety brush use is by Adams, part number SS164

R. Escalator Status Panel

1. The status panel shall be as located in Room 031-Police. The panel shall be illuminated illustrating all escalators identified by the design nomenclature: ES-1 through ES-4. Although ES-1 and 2 will be installed in this Contract, the panel shall also include the necessary hook-up system equipment for ES-3 and 4 future installation by others

2. The Escalator Status Control Panel shall be surfaced mounted in the Fire Management Control Room, with an overall size not to exceed 5"H x 7"W x 2 1/2"D. The status panel shall have a painted (sides and rear) metal enclosure (16 gauge) with a front cover of No. 4 Stainless Steel with beveled edges and engraved black in filled characters no less than 1/4 inch in height. The engraved characters shall have inlaid high contrast color. Status control shall illustrate the following

   a. Labeling of panel shall include the following: At top of panel, centered in all caps ESCALATOR STATUS PANEL. Header Row , NO., followed by each escalator number (1, 2, 3 and 4). The first column (below NO. Labeled as ON, UP, DN., E.S. and FLT.

   b. The "on" digital display (green light) will remain illuminated constantly when escalators are in operation, and the "up-down" digital display will illuminate only when the escalator is in the active "on" mode. The "off" function is performed by the "on" digital display, when escalators are not in operating condition.

   c. Escalator running direction: "Up" or "Down" arrows (green light) continuously illuminated when operating.

   d. Emergency Stop (E.S.): Indicator with flashing red light and Buzzer when the escalator is in the "Emergency Stop" mode. Note: When the escalator "on" light is deactivated due to safety device automatic cut of power, the digital display will remain blinking until reset at the controller. During an E.S. mode activation, it shall only be identified in the E.S. column on the status panel and shall ***not*** be displayed in the FLT column.

   e. Fault" mode (FLT.): Indicator with flashing red light indication and Buzzer when the escalator is in the Fault" Mode. Note: When the escalator "on" light is deactivated due to safety device automatic cut of power, the digital display will remain blinking until reset at the controller.

   f. There will be only two buzzers in the escalator status panel, one for the Equipment Failure mode, and the other for the Emergency Stop mode, connected to all escalators. In case of activation for the emergency stop button or the fault mode for each escalator, the buzzer will ring for a period of ten (10) seconds for the specific escalator and then automatically shut-off. This applies to activation by all mechanical safety devices, excluding the emergency stop buttons, which has, it's own identification mode. The status panel digital displays illuminated at the buzzer

activation will remain blinking until the problem has been fixed. The alarm panel accommodation for hearing the buzzer in the will have a microphone cutout hole, and will use the conduit cutouts. If two or more escalators have a fault mode simultaneously, the buzzer shall still ring four all escalators with a delay of five (5) seconds between each stored buzzer alarm.

S. Oil/Water Separator

1. Stainless steel (type 304), 11 GA, welded, leak proof unit with interior separator baffle. The assembly shall have a storage capacity (before overflow into the drain line) equal to the total of all the automatic lubricant reservoirs. The storage capacity of the oil/water separator shall not be less than two (2) and one-half (1/2) gallons. The oil/water separator shall provide total containment of liquids/solids with leak proof construction and connections.

   a. The oil/water access cover shall be of sufficient strength to support a concentrated weight of five hundred (500) pounds at any place on the access cover.

   b. The oil/water separator access cover shall provide a minimum opening of twelve (12) inches square for cleaning. The access cover drainage holes/slots shall reject a one-half (1/2) inch ball and provide a minimum of sixteen (16) square inches of free area drainage. Cover attachment shall be of screws/bolts (flat heads) of stainless steel. Fasteners shall not present a tripping hazard.

   c. Water drain outlet shall be oriented/located according to the Sanitary Drain Contract Documents sanitary drain line connection for a horizontal hook-up that allows positive drainage (1/8 inch per foot) into the sanitary system. The outlet shall be no less than two (2) inches in diameter, three (3) inches long and of schedule 40 stainless steel pipe.

PART 3 EXECUTION

3.01 INSTALLATION

A. Contractor shall install complete and operating escalators in accordance with manufacturer's instruction and approved shop drawings.

B. Contractor shall install special tools in the room storage cabinet as specified in part 2.04.

3.02 FIELD TESTING:

A. General

1. Contractor shall notify the Authority seven (7) days prior to each scheduled test contractor shall perform testing in the presence of an Authority representative.
2. Contractor shall notify the appropriate local authorities having jurisdiction a minimum of seven (7) days in advance of final acceptance tests.
3. Contractor shall provide all instruments, materials, and labor required for tests specified herein.

B. Acceptance Testing Requirements

1. Testing shall be performed in accordance with ASME A17.2.3 procedures with the following additions or adaptations.

2. Contractor shall perform the following tests on each escalator without load
   a. Comb impact device shall be tested and calibrated with an appropriate scale at both ends of the escalator in both the horizontal and vertical direction.
   b. Brakes: Measure deceleration rate with no load over 5 consecutive stops in the down direction using test equipment designed to obtain this information.
   c. *(Use only if vibration requirements of 1.05 are specified)* Escalator shall be tested to meet vibration requirements of section 1.05. The meter and the method shall be identical for all tests.
3. Contractor shall perform the following tests on each escalator under full load.
   a. Each escalator shall have a full load as specified in 2.01.B brake test performed on it. The stopping distance in the down direction shall meet all requirements of ASME A17.1.
   b. Twenty four hour test: the escalator shall operate continuously for 24 hours after the acceptance test with no faults. If any fault occurs that shuts the escalator down, the fault must be corrected and a new 24 hour test will begin.

PART 4 MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for the work of this Section complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

4.02 PAYMENT ITEMS

Item No.	Description	Unit
1421.000	ESCALATORS	LS

END OF SECTION

SECTION 15050

BASIC MATERIALS AND METHODS FOR MECHANCIAL WORK

PART 1 – GENERAL

1.01 DESCRIPTION

A. This Section specifies basic materials and methods and also summarizes the requirements for MECHANICAL Work of this Contract for complete sets of each type and complete systems of each type in accordance with Standard Section 15050 except as modified herein.

B. The Work of this Section consists of furnishing, installing, inspecting, and testing of the following, to result in finished, complete and operational equipment and systems.

C. The requirements for the individual components and types of equipment are specified in detailed mechanical technical sections including but not limited to the following, as applicable to each location:

Section 15250 – Insulation
Section 15400 – Plumbing Systems
Section 15500 – Fire Protection
Section 15600 – Heating, Ventilating, and Air Conditioning
Section 15800 – Air Distribution

1.06 PRODUCT DELIVERY, HANDLING AND STORAGE

C. Electrical resistance heaters that are an integral part of an electrical motor shall be energized during storage and during the period before permanent power is activated by temporary electric power and wiring.

D. Materials shall be stored in accordance with the manufacturer's recommendations in the original unopened protective packages and packages shall be marked to identify the contents.

E. Materials shall be stored with protection from the weather, humidity, temperature, dirt, dust, water and other contaminants.

1.08 OPERATION AND MAINTENANCE MANUALS

A. Submit and operation and maintenance manual for review for each item of equipment. After review and approval submit six copies of the manual bound in hardback binders. Furnish one complete manual prior to the time that equipment field acceptance tests are performed, and furnish the remaining manuals before the contract is completed. Inscribe the following identification of the cover: OPERATION AND MAINTENANCE MANUAL, name and location of the equipment and building, name of the Contractor and the Contract number. Include names, addresses, and telephone numbers of each subcontractor installing equipment and of the local representatives for each item of

equipment. Provide a table of contents with tab sheets placed before instruction covering the subject. Provide legible and easily readable instruction with large sheets or drawings folded in. Include wiring and control diagrams with data to explain detailed operation and control of each item of equipment; a control sequence describing start-up operation and shutdown; description of the function of each principal item of equipment; the procedure for starting, operating, shutdown, installation, and maintenance; lubrication schedules, including type, grade temperature range, and frequency; trouble shooting; safety precautions, diagrams, and illustrations; test procedures; performance data; and parts list. The parts list for equipment shall indicate the sources of supply, recommended spare parts, and the service organization that is convenient to the project site.

1.09 SAFETY REQUIREMENTS

A. Belts, pulleys, chains, gears, couplings, projecting set screws, keys, and other rotating parts shall be fully enclosed or properly guarded in accordance with OSHA requirements. High temperature equipment and piping so located as to endanger personnel or create a fire hazard shall be properly guarded or covered with insulation where required for safe operation and maintenance of equipment. Provide catwalks, ladders, and guide rails for equipment to allow for safe access.

1.10 MANUFACTURER'S RECOMMENDATIONS

A. Where installation procedures are required to be in accordance with manufacturer's recommendations, manufacturer is to furnish printed copies of these recommendations prior to installation. Installation of the item will not be allowed to proceed until the recommendations are received. Failure to furnish these recommendations can be cause for rejection of the material. Manufacturer's representative shall be present to supervise the installation of major pieces of equipment of systems. Prior to start-up, the manufacturers shall submit certificates that the equipment and systems have been installed in accordance with the manufacturer's requirements.

1.11 PROHIBITED MATERIALS

A. No equipment, materials, or items that contain lead, mercury, or asbestos shall be used on this project.

1.12 COORDINATION

A. Mechanical work shall be coordinated with that of other contracts and trades involved in the project construction. All work shall be carefully laid out in advance. Mechanical features shall be coordinated with those of architectural, structural, civil, and electrical features of construction.

1.13 CONTROL OF MATERIAL

A. All materials and equipment shall be new and of suitable grade for the intended use. Reconditioned equipment or used material shall not be acceptable. Before and during the installation period all damaged equipment shall be replaced at no additional cost to the Authority.

2.01 STANDARD PIPE AND FITTING CLASSES

D. Class D

2. Joints: Neoprene gasket, compression type; CISPI HSN 85.

P. Class P

1. Pipe 2 inches and Smaller: ASTM A53 Gr. B "Standard Specification for Pipe, Steel, Black and Hot dipped, Zinc-Coated, Welded and Seamless" schedule 40, black steel beveled ends for welding

R. Class R

1. Pipe 2 inches and Smaller: ASTM A53 Gr.B, schedule 80, galvanized steel, threaded.

S. Class S

1. Pipe: ASTM A53 Gr.B, schedule 80, black steel steel, screwed, flanged or welded

2. Fittings

a. ANSI B16.5, Type and Class of fittings to match adjacent piping

b. ANSI B16.5, to match adjacent piping per NFPA standards.

T. Class T

1. Pipe: ASTM A53 Schedule 40, black steel

V. Class V

1. Pipe: ASTM A53 GR. B seamless or ERW, schedule 40 steel, butt weld ends.

2. Fittings: 2-1/2 inch and Larger: 150 pound butt weld fittings per ANSI B16.9 and socket weld fittings per B16.11 for 2 inch and smaller.

3. Flanges: 150 pound weld neck or slip on flange, ANSI B16.5.

4. Joints: 2-1/2 inch and Larger: Welded, flanged, 2" and Smaller threaded or socket weld.

2.03 PIPE JOINT MATERIAL

C Arc-welding Electrodes: AWS A5.1

2.05 VALVES

C. Gate Valves

1. 2 inches and smaller: 150 pound bronze, non-rising stem, wedge disc, threaded ends, MSS-SP-80.

2. 2-1/2 inches and larger: 125 pound, iron body, non-rising stem, wedge disc, flange ends, MSS-SP-70.

2.06 UNIONS

A. Black steel pipe, 2 inches and smaller, ANSI B16.39, uncoated malleable iron or steel with brass/ bronze seats. 150 pound ratings, threaded ends.

2.08 GASKETS

D. Emergency generator exhaust, Class V piping: Spiral wound, type 304 stainless steel, non-asbestos filled, 3/16" thick with centering guide, 150 pound class, allowable operating temperature greater than 1000 deg F.

4.01 GENERAL. The work and items specified under this Section will be measured and paid for under the various sections specifying work involving their use.

END OF SECTION

SECTION 15250

INSULATION

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing and installing insulation for heating, ventilating, air conditioning, and plumbing systems in accordance with Standard Section 15250 of the Standard Specifications except as modified herein.

2.02 PIPING INSULATION

A. Types

6. Emergency Generator exhaust piping shall be insulated with Type D calcium silicate to a total aggregate thickness of 6 inches, except where noted otherwise on the drawings.

2.03 EQUIPMENT INSULATION

A. Types

5. Emergency Generator exhaust muffler shall be insulated with Type D calcium silicate to a total aggregate thickness of 6 inches.

2.05 INSULATION JACKETS

F. Insulation jacket for the emergency generator exhaust piping and muffler shall conform to paragraph D. " Metal Jackets" with glass cloth material at fittings and transitions

4.01 GENERAL. The work and items specified under this section will be measured and paid for under the various sections specifying work involving their use.

END OF SECTION

SECTION 15400

PLUMBING SYSTEMS

PART 1 – GENERAL

1.01 DESCRIPTION

A. This Section specifies demolishing existing sewage ejector and track drainage pumping systems as indicated on the Contract Plans and furnishing and installing plumbing systems in accordance with Standard Section 15400 except as herein modified.

C. Applicable requirements of Section 02050 Demolition apply to work outlined in this Section.

PART 2 – PRODUCTS

2.01 PIPING AND FITTINGS. Service shall be as indicated unless otherwise shown on drawings.

F. Forced Mains: Class P or Class T

G. Emergency Generator Exhaust: Class V

H. Ductile Iron Pipe: Class V

2.05 WATER CLOSET: ASME A112.19.2M

A. Water Closet: Siphon jet, wall hung, vitreous china, 1-1/2" spud, 1.6 gpf, Mounting height to accommodate ADA.

B. Flush Valve: Water saver, supply control valve having non-hold open feature, tamper proof trim, wall plate, backflow preventer, flush pipe and escutcheon for inlet spud.

C. Seat: Black with stainless steel check hinge.

2.11 CHAIR SUPPORTS FOR WALL HUNG FIXTURES

A. Water Closets: ASME A112.19.2M

2.16 DRAINS

F. TRENCH DRAINS-Modular precast polymer concrete, cast iron or polyester fiberglass trench sections with presloped 4" wide radiused interior waterways, knockouts, end caps, cast iron frame and slotted ductile iron grate, extra heavy duty rated, stainless steel grate hold downs.

G. HUB DRAINS- Cast iron hub section up 2" min. above floor level, with full-sized deep seal P-trap.

2.17 TRAPS

C. Trap Primers- ASSE 1018 - Trap Seal Primer Valves, Bronze body, O-ring seals, integral threaded outlet vacuum breaker, adjustable.

2.23 SUBMERSIBLE SUMP PUMPS

Provide simplex submersible sump pumps for escalator and elevator sumps that are vertically mounted centrifugal type with capacities and configured as indicated. Provide discharge connections located and fitted as indicated. Provide each pump with a liquid level control switch and 25 foot power cord.

A. Motor – Single phase, air-filled, hermetically sealed, Class F insulation, sealed ball bearings, automatic thermal overload protection.

B. Pump – Cast iron case and impeller, tandem seals, and stainless steel hardware. Pump shall capable of passing ½ inch solids.

2.24 SEWAGE PUMPS

B. Pumps

1. Provide wet-pit centrifugal duplex pump and grinder system conforming to MIL-P-21251 having a minimum capacity rating at head as indicated.

5. Grinders shall have stainless steel cutter plates and blades that are protected from abrasives.

D. Controls.

1. Provide a prefabricated packaged level control system using float-actuated sensing devices with warning light and audible alarm. Sequence of operation shall be as indicated.

2.25 OIL/WATER INTERCEPTOR

A. Provide oil/water interceptors for receiving discharge from the escalator and elevator sump pits. Interceptors shall be a special purpose factory assembled unit which is the standard product of a manufacturer regularly engaged in the production of such equipment with similar units for a minimum period of ten years.

B. The interceptor shall be designed for intermittent flows of water, oil and/or any combination of non-emulsified oil/water mixtures from zero flow up to 100% of maximum hydraulic capacity and provide water effluents which meet continuous discharge requirements of 10 ppm or less of oil and grease. The interceptors shall meet all Federal, State, and Local requirements.

C. The interceptor shall be designed in a manner to minimize solids build up in the oil/water interceptor chamber, which could reduce the oil/water separation of the unit.

D. Construction of the Unit:

1. The interior and exterior shell shall be constructed of steel and structurally designed to withstand the loads it is subjected to.

2. A remote mounted indicating panel shall be provided with power, oil level lights, and an audible high-level alarm.

3. The interceptor shall be suitable for servicing from the top.

4. The interceptor shall be furnished with a secured gasketed nonskid cover.

5. The interceptor shall be furnished with fittings for vent and waste oil draw-off.

6. The interceptor shall be constructed for transport to construction site as one integral unit, ready for installation (field splicing or field fabrication are unacceptable).

7. Maintenance and entry hardware shall be stainless steel.

8. The oil/water interceptor shall have the capacity indicated on the Contract drawings.

2.26 BACKWATER VALVES

A. Backwater Valves: ANSI A112.14.1. Hub and spigot or No-Hub inlet and outlet cast iron body, cast iron, gasketed bolted access cover, bronze valve. Flapper to hang in closed position during non-operation period.

2.27 HOSE BIBBS/ WALL HYDRANT

A. Provide hose bibbs and wall hydrants as shown on Contract drawings. Install frost proof wall hydrants in areas subject to freezing temperatures.

B. Hose Bibbs-Bronze or brass construction hose faucet/valve, cast iron hand wheel, replaceable disc, hose thread spout, with ASSE 1011 backflow preventer outlet, 3/4" size.

C. Wall Hydrant- ASSE 1019 - Wall Hydrants, Frost Proof Automatic Draining, Anti-Backflow Type. Freezeproof automatic draining wall hydrant in flush mounted cast brass wall box with locking door, 3/4" inlet, 3/4" hose thread ASSE 1019-93 backflow preventer outlet, loose key operator, polished brass finish.

2.28 TRACK DRAINAGE PUMPS

A. General. Provide a duplex pump unit capable of being mounted as indicated.

B. Pumps

1. Provide centrifugal type pumps conforming to class and style indicated. Provide flanged discharge connections located and fitted to connect to existing discharge piping stub out. Stub out to be provided during demolition of the track drainage piping and appurtenances in accordance with Contact drawings.

2. Each pump shall have the minimum capacity rating at the head specified.

3. Shafts shall be stainless steel with pressed sleeves.

4. Totally enclosed pump impellers capable of passing 3-inch diameter solid spheres.

C. Motors

1. Provide pumps with NEMA rated motors as indicated on Contract drawings.

D. Track Drainage Pump Controls

1. Provide one NEMA 4X stainless steel control panel, with AC and DC compartments to serve both pumps, suitable for receiving power from 480 VAC and 600VDC, as required for the each pump.

2. Provide one DC resistor enclosure to house pump resistors.

3. Provide the following features for the control panel.

a. Alternating pump starts to equalize runtime.
b. Disconnects for the AC and DC feed.
c. AC and DC power available pilot lights.
d. Elapsed time meters for each pump.
e. Run pilot lights for each pump.
f. Start and stop pushbuttons for each pump.
g. Hand-Off-Auto switch for each pump.
h. High level alarm pilot light.
i. Alarm reset, silence and test pushbuttons.
j. Rheostat for DC pump speed control.
k. Control panel space heaters.
l. Lead-lag pump starting.

3.02 INSTALLATION

A. Install plumbing systems in accordance section 15050 and as indicated herein.

B. Set floor drains, area drains, trench drains and cleanouts level and plumb adjusted to finished floor elevation or finished wall location. Locate where serviceable.

C. Allow minimum of 18" clearance around cleanouts for rodding. Lubricate threaded cleanout plugs with graphite and oil, teflon tape or waterproof grease.

D. Install trap primer connections where indicated.

E. Provide deep seal traps on floor and area drains.

F. Set backwater valves on undisturbed soil or compacted granular backfill level and plumb with top adjusted to finished floor elevation. Test and adjust valve for proper operation. Allow minimum 18" clearance for servicing.

G. Install water hammer arrestors where indicated and at quick closing valve installations.

H. Install backflow preventers in accordance with Massachusetts Plumbing Code maintaining minimum clearance distances for servicing and testing. Provide indirect waste piping with air gap installation from relief opening to above hub drain or floor drain.

I. Mount wall hydrants recessed in wall construction with valve plug extended beyond interior side of building insulation. Slope to drain to exterior. Install so discharge is 18" min. above finished grade. Set wall box in grout or caulk and fill wall penetration with insulation.

J. Mount hose bibbs securely fastened to wall where indicated.

K. Provide water hammer arrestor in line to hose bib and wall hydrants.

L. Demolish existing track drainage pumps, piping, and appurtenances. Leave stub out for connection of new track drainage pump discharge piping.

3.03 VENT SHAFT B3 AT ABANDONED TURN AROUND LOOP

A. Install 6" Ductile Iron drain pipe including floor drains and cleanouts in the turnaround loop infill slab for drainage

PART 4 – MEASUREMENT

4.02 PAYMENT. Plumbing will be paid for at the Contract lump sum price for plumbing. Plumbing demolition is paid for in Section 02050.

ITEM NUMBER	PAYMENT ITEM	UNIT
1501.000	PLUMBING	LUMP SUM

END OF SECTION

SECTION 15500

FIRE PROTECTION

PART 1 – GENERAL

1.01 DESCRIPTION

A. This Section specifies demolishing the existing fire protection systems as indicated and furnishing and installing new interior fire protection systems in accordance with Standard Section 15550 of the Standard Specifications except as modified herein.

C. Protection Systems. Interior fire protection systems shall include the following, as indicated:

5. Clean agent system.

This specification outlines the requirements for a Clean Agent Fire Suppression System with automatic detection and control. The work described in this specification includes all engineering, labor, materials, equipment and services necessary, and required, to provide a complete, tested, and operational suppression system.

1.02 QUALITY CONTROL

A. Requirements of Regulatory Agencies

Design and provide fire protection systems conforming to the applicable requirements of the following:

1. NFPA 10 Portable Fire Extinguishers
5. NFPA 13 Installation of Sprinkler Systems
6. NFPA 14 Installation of Standpipe, Private Hydrant, and Hose Systems
7. NFPA 70 National Electric Code
8. NFPA 72 National Fire Alarm Code
9. NFPA. 2001 Clean Agent Fire Extinguishing Systems
10. FM Global Property Loss Prevention Data Sheet No. 4-9 "Clean Agent Fire Extinguishing Systems" (Included in this Section.)
11. Factory Mutual Systems (FM) Publication - Factory Mutual Approval Guide
12. Massachusetts Building Code, 780 CMR, Chapter 13, Fire protection.
13. Americans with Disabilities Act, Title 24, Latest Edition

13. The standards listed, as well as all other applicable codes and standards, shall be used as "minimum" design standards. Also to be considered are good engineering practices.

B. The manufacturer of the clean agent system hardware and detection components shall have a minimum of 5 years experience in the design and manufacture of similar types of suppression systems and can refer to similar installations providing satisfactory service.

C. All devices and equipment shall be UL listed and/or FM approved.

D. Demolition of existing fire protection equipment shall be in accordance with the applicable portions of Specification Section 02050 Demolition and the Contract Plans.

E. Relocation of Dry Standpipe System

When relocating the dry standpipe system, all procedures as spelled out in the Chairman's Directive No. 59 (revised) shall be adhered to. This document is attached as pages 2a through 2d. Contractor shall be held responsible for knowledge and execution of applicable requirements. In addition, notification to the Boston Fire Department shall take place prior to any temporary shut downs or changes in the system.

1.03 SUBMITTALS

B. Shop Drawings

All shop drawings regarding the clean agent system shall be forwarded by the Owner/Engineer to FM Global Insurance Company for their review and approval per FM Global Property Loss Prevention Data Sheets 4-9 (Ref. 10).

3. Clean Agent System

a. Submit drawings for the clean agent systems showing material and equipment information. Information shall include manufacturer's catalog cut sheets and technical data for each component or device used in the system. This shall include, but not be limited to, the following:

1. Detectors
2. Manual discharge switches
3. Control panel
4. Release devices
5. Alarm devices

6. Agent storage cylinders
7. Mounting brackets
8. Discharge Nozzles
9. Abort stations
10. Piping isometrics
11. Flow calculations
12. Battery stand-by power supply calculations

b. Drawings shall indicate locations, installation details and operation details of all equipment associated with the clean agent system. Floor plans shall be provided showing equipment locations, piping, point-to-point wiring, point-to-point electrical layout drawings and other details as required. Elevations, cross sections and other details shall be drawn to a larger scale as required.

c. Sequence of operation, electrical schematics and connection diagrams shall be provided to completely describe the operation of the clean agent system controls.

d. Computerized verification of flow calculations shall be submitted for each fire suppression system and include the following data as a minimum:

1. Quantity of agent per nozzle
2. Orifice union/nipple and nozzle orifice diameters
3. Pressure at nozzle (psi)
4. Nozzle body nominal pipe size (inch)
5. Number and size of cylinders
6. Total agent
7. Pipe size per pipe section
8. Pipe schedule per pipe section
9. Number, size and type of fitting per pipe section
10. Actual length per pipe section (feet)
11. Equivalent length per pipe section (feet)
12. Discharge time (seconds)

F. Operation and Maintenance Data

3. Clean agent system – Provide information outlining the operation and maintenance procedures that will be required of the owner. This information shall explain any special knowledge or tools the owner will be required to employ and all spare parts that should be readily available.

G. Test Procedures

1. Test procedures shall be submitted for review indicating step-by-step procedures for final installation acceptance testing of the clean agent fire suppression system. Notification shall be given to the Engineer 14 days prior to the test to allow the Engineer to witness the testing.

PART 2 – PRODUCTS

2.02 DRY STANDPIPE

A. Pipe: ASTM A53 Gr. B, "Standard Specification for Pipe, Steel, Black and Hot Dipped, Welded and Seamless" galvanized, schedule 40, with square cut grooves

G. Air Vacuum Release Valves: Air/Vacuum Valve shall consist of a body, cover, baffle, float and seat. The baffle will be designed to protect the float from direct contact of the rushing air and water to prevent the float from closing prematurely. The seat shall be fastened into the valve cover without distortion and shall be easily removed.

The float shall be stainless steel, and shall be center guided into the seat. Air/Vacuum Valves shall be sizes 1/2" through 3" and shall have NPT threaded outlets for installation of street elbow or mushroom cap.

All materials of construction shall conform to A.S.T.M. specifications as follows:

- Body and cover Cast iron ASTM A126 Gr. B "Standard specification for gray iron castings for valves, and pipe fittings"
- Float Stainless steel ASTM A240 "Standard specification for chromium and chromium-nickel stainless steel plate, sheet, and strip for pressure vessels for general applications."
- Seat Buna-N

Exterior paint Universal Metal Primer FDA approved for potable water contact
Protector hood Steel

2.07 CLEAN AGENT FIRE SUPPRESSION SYSTEM

A. System Description and Operation

1. Materials and equipment shall be of a single manufacturer. The name of the manufacturer and serial numbers shall appear on all major components.

2. The system shall be a clean agent fire suppression system designed to provide a uniform concentration of the clean agent for the protected area.

The amount of clean agent to be provided shall obtain a uniform minimum concentration as required. The design concentration shall be by volume at 70°F.

3. Either counting zone detection circuits or cross-zoned detection circuits shall automatically actuate the system. Smoke detectors shall be ionization detectors and photoelectric with compatibility listings for use with the control unit. The detectors shall be alternated throughout the protected area with the system requiring two (2) detectors in alarm prior to automatic agent release.

B. Sequence of Operation

1. Activation of any single detector in any detection zone shall cause a first-stage alarm and energize a lamp on the activated detector and control panel.

2. Activation of a detector on the second zone shall transmit an alarm signal to remote monitoring or building alarm panel, cause a second-stage (pre-discharge) alarm to operate, operate auxiliary contacts for air conditioning shutdowns and automatic dampers, and initiate a programmable time delay for agent release.

3. Upon completion of the time delay the system shall cause a discharge alarm to be activated, activate visual alarms (strobe) at protected area entrance, and a energize control solenoid for cylinders to release gaseous agent into the protected area. At the option of the owner the discharge alarm shall operate auxiliary contacts for emergency power off of all electrical equipment in the zone. (excluding lighting and emergency circuits for life safety)

C Auxiliary Components

1. Double action manual releasing stations shall be provided at each exit of the protected area and shall, when activated, immediately release the gaseous agent and cause all audible/visual alarms to activate. In addition, activation of the manual releasing stations shall cause immediate shutdown of air and power circuits.

2. Abort stations shall be provided at each exit of the protected area and shall, when operated, interrupt the discharge of gaseous agent and emergency power-off functions. The abort stations shall be momentary devices (dead-man) requiring constant pressure to maintain contact closure. Note: Manual Releasing Station activation shall override any abort station. Abort station operation shall be per IRI and FM guidelines.

3. A graphic annunciator shall be provided at the control panel location. The graphic annunciator shall be provided by the equipment manufacturer in an approved NEMA enclosure with keyed faceplate. The graphic annunciator shall display the entire clean agent protected area and shall indicate each smoke detector and its proximity. Smoke detectors, when activated, will individually annunciate at the graphic annunciator as follows, as applicable:

Ceiling Detector:	Red LED
Sub-floor Detector:	Amber LED

4. All control systems shall be UL Listed or FM approved and be utilized with listed or approved compatible operating devices and shall be capable of the following features:

a. Ground fault indication
b. Supervised detection circuit(s)
c. Supervised alarm circuit(s)
d. Supervised release circuit(s)
e. Supervised manual pull circuit (if applicable)
f. Supervised primary power circuits
g. Alarm overrides trouble logic
h. Battery standby
i. Front panel indicating lamps (LEDs)
j. Key lock steel enclosure
k. Programmable time delay
l. Programmable detection logic
m. Prioritized trouble logic
n. Microprocessor based logic
o. History buffer

5. The control panel shall communicate with and control the following types of equipment used to make up the system: smoke detectors, manual release/abort stations, alarm notification appliances, releasing components and other system controlled devices.

a. The control panel shall be housed in a cabinet designed for mounting directly to a wall or vertical surface. The back box and door shall be constructed of .060 steel with provisions for electrical conduit connections into the sides and top. The door shall provide a key lock and include a glass or other transparent opening for viewing of all indicators. Space shall be provided in the cabinet for standby power batteries.

b. System Display - The system display shall indicate the status of the following system parameters:

AC POWER:	Green LED
SYSTEM ALARM:	Red LED
RELEASE:	Red LED
SUPERVISORY:	Yellow LED
SYSTEM TROUBLE:	Yellow LED
CIRCUIT TROUBLE:	Yellow LED
ALARM SILENCED:	Yellow LED
POWER TROUBLE:	Yellow LED

c. The control panel shall also include the following functions:

(1) Output circuits shall be protected against false activations by using a 2-step electronic activation circuit.
(2) Battery/earth fault supervision shall be provided.
(3) Adjustable delay timer shall be available, zero to thirty seconds.
(4) Cross-zone option shall be selectable (two zones in alarm before release).
(5) Three abort functions options shall be selectable: Standard UL method, IRI method and local AHJ method.
(6) A second release circuit may be selected in place of the supervisory circuit.
(7) A supervised manual release circuit shall be provided which, when activated, shall override the Abort.
(8) Ninety hours of standby battery power shall be provided.
(9) A watchdog timer to supervise microprocessor shall be provided.
(10) Slide-in zone identification labels shall be provided.

d. System Control Switch Operation

(1) Tone Silence Switch: Activation of the control panel tone silence switch in response to alarms, troubles, and supervisory conditions shall silence the local panel piezo electric signal and change the system alarm or trouble LED from flashing mode to steady ON mode. Occurrence of any new alarm or trouble conditions in the system shall cause the control panel to resound the local piezo sounder and repeat the alarm or trouble sequences.

(2) Alarm Silence Switch: Activation of the alarm signal silence switch shall cause all alarm notification appliances to return to the normal condition after an alarm condition.

(3) System Reset Switch: Activation of the system reset switch shall cause all electronically-latched initiating devices, appliances as well as all associated output devices and circuits, to return to their normal condition. Holding system reset down shall perform a LAMP TEST function and will activate the piezo sounder.

(4) Alarm Activate Switch: Operation of the alarm activate switch shall activate both notification circuits and the alarm relay. Alarm activation shall be a latching function.

e. System Operation

(1) Zone Status LEDs: The alarm, supervisory or trouble LED(s) shall flash until event(s) has been acknowledged. Any subsequent new alarm, supervisory or trouble condition will resound all indications and flash new events.

(2) Supervisory: A short circuit on this zone shall cause the supervisory LED to flash. The tone silence switch shall silence the piezo causing the supervisory LED to illuminate steady. An open circuit shall report as a zone trouble.

(3) Zone Disable: Disable/enable of any initiating circuit shall be accomplished using a special sequence of operation of the four control switches. If a zone has been disabled, an alarm shall activate the red zone LED but not the piezo or any output circuit.

(4) Last Event Recall: Last event recall shall allow the user to display the previous panel status. Last event recall may be used to diagnose intermittent trouble conditions.

f. The power supply shall be integral to the control panel and provide all control panel and peripheral device power needs.

(1) Input power shall be 120 VAC, 60 Hz. The power supply shall provide an integral battery charger for use with batteries up to 15 AH.

(2) The power supply shall be designed to meet UL and NFPA requirements for power limited operation on all notification and initiating circuits.

(3) Positive-temperature-coefficient thermistors, circuit breakers, fuses, or other over current protection shall be provided on all power outputs.

(4) Batteries shall be 2 - 12 volt, Gel-Cell type providing 24 VDC. Batteries shall have sufficient capacity to power the fire alarm system for not less than 24 hours in standby plus 5 minutes of alarm upon a normal AC power failure. The batteries are to be completely maintenance free. No liquids are required. Fluid level checks, refilling, spills and leakage shall not be accepted.

4. Smoke Detectors – Smoke detectors shall be 24 VDC and shall be UL listed and FM approved. Detectors shall be wired using either a Class "A" or Class "B" wiring arrangement. No other detection / wiring arrangements will be acceptable.

a. Each detector shall include a visual status indicator, provide remote LED output, and include a built-in test capability.

b. The sensitivity shall be factory set per UL 268.

c. The detector cover and screen shall be easily removable for field cleaning.

d. A special vandal-resistant locking screw shall be provided to lock the head to the base.

e. The head-to-base connection shall be made by use of bifurcated contacts. Terminal connections to the base shall be the screw types that are accessible with the base installed on the mounting box.

f. Where specifically identified on the contract drawings, detector bases shall incorporate a relay with Form C contacts rated at 1 amp, 120 VAC or 28 VDC for remote LED alarm annunciation of the detector.

g. Ionization-type smoke detector shall be the dual chamber type and compatible with the control system. The detector shall have an LED in its base that illuminates in a steady-on mode when in alarm and pulse mode when in standby. The control unit reset switch shall reset of the detector.

h. The design of the ionization detector compensating circuits shall provide stable operation with regard to minor changes in temperature, humidity and atmospheric conditions.

5. Indicating Appliances

a. Sounder/Strobe Combination

(1) The sounder/strobe, as separate units or a combination unit shall operate on 24 VDC and shall be approved for use with the listed control system.

(2) The sounder/strobe combination shall be polarized and powered from the control unit.

(3). The strobe shall be listed to UL Standard 1971 for the Hearing Impaired, approved for Fire Protective Service, and rated at either 15 cd or 75 cd.

(4) The sounder shall have eight (8) tone options selected by means of programming clips.

(5) All alarm horns and strobes shall comply with the Boston Fire Department rules and regulations including ADA considerations.

6. Manual Pull Stations

a. The manual pull stations shall UL listed, dual action and be provided for the release (electrical) of the fire suppression system in case of an emergency.

b. Manual stations shall be metal with clearly visible operating instructions provided on the cover. The word FIRE shall appear on the front and both sides of the stations.

7 Abort Switch

a. The abort switch shall be used where an investigative delay is desired between detection and actuation of the fire suppression system.

b. This switch shall be a momentary contact "dead-man" type switch requiring constant pressure to transfer one set of contacts. Clear operating instructions shall be provided at the abort switch.

8 Maintenance Lock-Out Switch

a. The maintenance lock-out switch shall be used where it is desired to disable the fire suppression system during routine maintenance.

b. This switch shall be key operated allowing removal of the key in either the "Normal" or "Lock-Out" position. A red indicator lamp shall be included on the switch assembly to be illuminated when in the "Lock-Out" position. The control unit is to indicate a trouble condition when in the "Lock-Out" position.

9. Selector Switch

a. The selector switch shall be used where a connected reserve is required.

b. This switch shall be key operated allowing removal of the key in either the "Main" or "Reserve" position.

10. Storage Cylinders

a. Cylinder assemblies shall be of steel construction with a standard RED epoxy paint finish. Each cylinder shall be equipped with a pressure seat-type valve and gauge. Each valve shall also include a safety pressure relief device that provides relief at 3000-3360 PSI per Compressed Gas Association (**CGA**) test methods.

b. Filling of the cylinder assembly shall be by an authorized distributor in conjunction with a factory authorized agent filling station. Initial filling and recharge shall be performed in accordance with the manufacturer's established procedures and shall not require replacement components for normal service.

11. Cylinder Bracket

a. Each cylinder assembly shall be furnished with a bracket made from welded steel. The bracket shall hold the cylinders in a saddle with a front bracket piece that secures the cylinders. The brackets shall be modular in design to allow added bracketing or stacking of cylinders depending on installation requirements.

b. Cylinder brackets shall be UL listed and/or FM approved for use with the system.

12. Valve Actuators

a. Electric valve actuators shall be stackable with swivel connections to allow removal of actuators for maintenance or testing.

b. Operation of actuators shall not require replacement of components. No electro-explosive devices may be used to actuate the valve assembly.

c. Electric actuators shall be continuous duty.

d. Actuation devices shall be UL listed and/or FM approved for use with the system.

13. Discharge Hose/Check Valve

a. When manifolding, all cylinder assemblies shall include a flexible discharge hose and check valve for connection to the manifold inlet.

b. All hose/check valves shall be UL listed and/or FM approved for use with the system valves.

14. Discharge Nozzles

a. Discharge nozzles shall be of two-piece construction and sized to provide flow rates in accordance with system design flow calculations.

b. A nozzle inlet orifice plate shall be included. A computerized UL listed flow calculation program shall determine the orifice size. Orifice(s) shall be machined in the nozzle body to provide a horizontal discharge pattern based upon the approved coverage arrangements.

c. Nozzles shall be permanently marked with the manufacturer's part number. The nozzles shall be threaded directly to the discharge piping without the use of special adapters.

d. Nozzles shall be UL listed for use with the system.

15. Orifice Union/Nipple Assemblies

a. An orifice union/nipple shall be included in the manifold to reduce pressure in the downstream pipe network.

b. Orifice union/nipple assemblies shall be rated at 2000 lb. Class minimum.

c. Orifice union/nipple assemblies shall be permanently marked with the manufacturer's orifice code. The orifice union/nipple shall be threaded directly to the manifold piping without the use of special adapters.

d. Orifice union/nipple assemblies shall be UL Listed and/or FM Approved for use with the system.

PART 3 – EXECUTION

3.01 GENERAL

F. Connections and Joints. Provide threaded connections, grooved, and brazed and soldered joints complying with NFPA 13.

I. Seismic Supports and Restraint- All fire suppression systems shall be supported and restrained for seismic conditions in accordance with NFPA 13

3.02 DRY STANDPIPE

F. Install air vacuum release valves at high points in the standpipe system

G. Relocate existing dry standpipe as required to prevent interference with the proposed east fan room for Vent Shaft B3. Please refer to the Contract Drawings for additional information.

3.03 CLEAN AGENT SYSTEM

A. All electrical enclosures, raceways and conduits shall be installed in accordance with applicable codes and intended use and contain only those electrical circuits associated with the fire detection and control system and shall not contain any circuit that is unrelated to the system.

B. Unless specifically provided otherwise in each case, all conductors shall be enclosed in steel conduit, rigid or thin wall as conditions dictate.

C. Any conduit or raceway exposed to weather or other similar conditions shall be properly sealed and installed to prevent damage. Provisions for draining and/or drying shall be employed.

D. NEMA rating and/or electrically hazardous classifications shall be observed and any equipment or materials installed must meet or exceed the requirements of service.

E. Any wiring shall be of the proper size to conduct the circuit current but shall not be smaller than #18 AWG unless otherwise specified for a given purpose. Wire that has scrapes, nicks, gouges or crushed insulation shall not be used. The use of aluminum wire is strictly prohibited.

F. Splicing of circuits shall be kept to a minimum and are only to be found in an electrical device suited for the purpose.

G. Wire spliced together shall have the same color insulation.

H. Wire splices shall be made with appropriate devices suited for the purpose.

I. All wire terminations shall be made with crimp terminals unless the device at the termination is designed for bare wire terminations.

J. All electrical circuits shall be numerically tagged with suitable devices at the terminating point and/or splice. All circuit numbers shall correspond with the installation drawings.

K. White colored wire shall be used exclusively for the identification of the neutral conductor of an alternating current circuit.

L. Green colored wire shall be used exclusively for the identification of the earth ground conductor of an AC or DC circuit.

M. All agent storage cylinders shall be centrally located as vertical, free-standing cylinders with wall and/or floor mounted retaining brackets. Where multiple cylinders are required for the same hazard, a common manifold shall be employed. (Cylinders mounted horizontally shall be installed in accordance to the manufacturer's recommendations.)

N. On multiple cylinder arrangements (discharging into a common hazard), one cylinder shall be designated as the pilot cylinder and employ the restorable electric actuator, mechanical manual actuator, or both. All remaining cylinders shall be pneumatically operated from the gaseous agent.

O. Manifolded cylinders shall employ a flexible discharge hose to facilitate installation and system maintenance. Each cylinder on a manifold shall also include an agent check valve installed to the manifold inlet.

P. System piping shall be of non-combustible materials having physical and chemical characteristics such that its integrity under stress can be predicted with reliability.

Q. As a minimum, piping materials shall be black steel pipe conforming to ASTM A-53A ERW or ASTM A-106A seamless.

R. Piping joints shall be suitable for the design conditions and shall be selected with consideration of joint tightness and mechanical strength.

S. As a minimum, fittings beyond the orifice union/nipple shall be black, 300 lb. class fittings conforming to ANSI B-16.3. Ordinary cast iron fittings shall not be used. Distribution piping downstream of the orifice union must be a minimum of Schedule 40.

T. The system manifold up to the orifice union/nipple must be constructed of Schedule 80 piping and 2000 lb. or 3000 lb. forged steel fittings.

U. All piping shall comply with NFPA 2001.

V. Piping shall be installed in accordance with good commercial practice to the appropriate codes, securely supported with UL Listed hangers and arranged with close attention to the design layout since deviations may alter the design flow performance as calculated.

W. Piping shall be bracketed within 12" (.3 m) of all discharge nozzles.

X. All piping shall be reamed, blown clear and swabbed with appropriate solvent to remove mill varnish and cutting oils before assembly.

Y. Multi-outlet fittings other than tees shall not be permitted.

Z. Assembly of all joints shall conform to the appropriate standards. Threaded pipe joints shall utilize Teflon tape applied to the male threads only.

3.04 FIELD QUALITY CONTROL

A. Preparation

1. General. Prior to acceptance testing, fire protection systems shall be flushed and then disinfected (with the exception of clean agent systems).

2. Flushing. Flush fire protection systems with clean water until it is free of scale, slag, dirt, grease or other foreign material in accordance with applicable requirements of Station 1.02.A.

3. Disinfection. Disinfect systems by filling them with solution containing not less than 50 parts per million of chlorine and let stand for minimum 24 hours. Then flush systems with clean water until residual chlorine is not greater than 0.2 parts per million.

B. Acceptance Testing Certification and Approvals

1. Perform acceptance testing and certification of fire protection and suppression systems and obtain approvals in accordance with applicable requirements of Station 1.02.A.

2. The complete system shall be functionally tested, in the presence of the owner or his representative and the agency having jurisdiction, and all functions, including system and equipment interlocks, must be operational at least five (5) days prior to the final acceptance tests.

3. Approval of the clean agent installation shall be in accordance with the requirements of NFPA 2001 and the Boston Fire Department.

4.02 PAYMENT. Fire protection systems will be paid for at the Contract lump sum price.

ITEM NUMBER	PAYMENT ITEM	UNIT
1025.010	INTERIOR FIRE PROTECTION	LUMP SUM
1551.025	RELOCATION OF DRY STANDPIPE	LINEAR FEET

END OF SECTION

Chairman's Directive No. 59 Revised

Subject: **Fire Control System/Security Program**

The purpose of a fire control system, i.e., alarms, smoke or heat detectors, special extinguishing systems (halon), sprinklers, indicating valves, hydrants, standpipes and portable extinguishers, etc., is to provide
safe environment for the Authority's passengers and employees and to protect the Authority's property and equipment. In order to insure the effectiveness of our fire control systems the following guidelines will be strictly adhered to.

I. PRIORITY IN WORKLOAD SCHEDULING

A. Fire control systems, when down, will receive priority in Engineering and Maintenance and workload scheduling

B. These priorities will be set by the Engineering and Maintenance Department, subject to appeal from the Office of Safetv.

II. REPORTING PROCEDURES

A. General ... For All Authority Employees

In order to insure the effectiveness of our fire control systems, it is the responsibility of each employee to report, any impairment which is observed in a fire control system within his or her work location. When an impairment is noted or any fire control system is withdrawn from or restored to service the Central Control Dispatcher

B. Transportation Department - Central Control

The Central Control Dispatchers, upon notification, must ascertain the pertinent information, i.e., time, location, problem, cause and estimated time of impairment, in order to disseminate the information to the Engineering and Maintenance Department, senior official at the affected location and the Office of Safety.

C. Engineering and Maintenance Department

Should it be necessary for the Engineering and Maintenance Department to shut down or render ineffective an existing fire control system, or should any fire control system be rendered inoperable by accident for a period longer than eight (8) hours, the Chief Engineer or his designee must notify the

Central Control Dispatcher (Ext. 5777 or 5707), the jurisdictional fire department and the Engineering and Maintenance Dispatcher (Ext. 5278). In the notification procedure one should note the location, problem, cause and estimated time of impairment. Any Engineering and Maintenance Department personnel having to render inoperable any fire control system is responsible for tagging the system with an "out of service" sign.

D. **Officials in Charge of Facility**

Upon notification from Central Control that a fire suppression system or alarm system has been taken out of service for repairs or rendered unserviceable due to damage, the senior official at the affected facility must insure that proper fire procedures involving fire prevention is adhered to; namely:

1. Document the notification and pass the word on so that successive shifts are apprised of this condition.

2. In the event of an alarm system loss, that any fire occurrence be transmitted immediately to Central Control, requesting the fire department, reminding Central Control that the local alarm direct to fire headquarters is out of service.

3. In the event of fire suppression system loss, i.e., sprinklers, etc., welding, cutting and other activities must be carefully controlled and fire extinguishers must be brought into even more immediate access prior to the performance of those tasks.

E. **Construction Directorate**

Construction Directorate personnel and/or those responsible for contractors shall provide reasonable advance notice, preferably one week's notice, in writing, to the Chief Engineer of the Engineering and Maintenance Department of any anticipated project which would render any existing fire control system inoperable, in order to obtain the Chief Engineer's permission before the existing fire control system or part thereof is rendered inoperable. Should an emergency situation exist which requires the impairment of a fire control system, the Chief Engineer must be notified immediately by called 722-5278. The Chief Engineer or his designee is responsible for notifying the Central Control Dispatcher (Ext. 5777 or 5707) when a priority situation is reported or when permission has been granted to render inoperable an existing fire control system.

F. **Office of Safety**

The Office of Safety's duty person, upon notification by the Central Control Dispatcher, will contact the senior official

on the shift at the affected facility and speak to him to insure that the above procedures are being carried out. Safety's duty person (in case of weekend duty) will call or drop in on subsequent shifts randomly to see that procedures are being communicated and adhered to.

III. INSPECTION AND DOCUMENTATION

All fire control system equipment will be inspected in the following manner:

A. Fire Extinguishers

A visual inspection by the Safety Coordinator at each facility on a weekly basis. Defects must be reported to Engineering and Maintenance (Ext. 5278.

2. Inspection by outside contractors - once a year. The Engineering and Maintenance Department will forward a written report, dated and signed by the inspector to the office of Safety, c/o the Supervisor in Fire Prevention.

3. The Supervisor in Fire Prevention of the Office of Safety will maintain a master list of all sprinklered facilities by location and initiate a check-off procedure using the status report from Engineering and Maintenance to insure compliance and follow-upon systems that are down.

B. City Boxes Fire Alarms

A visual inspection will be made by the Authority's Signal Department personnel on a weekly basis.

2. **Master Boxes**

a. Boston Only - Master Boxes will be inspected on a monthly basis by an outside contractor. The Engineering and Maintenance Department will forward a written report on these inspections to the Office of Safety, c/o Supervisor in Fire Prevention to insure compliance and follow-up.

b. Master Boxes in Cities and Towns other than Boston will be inspected in accordance with local ordinances or regulations. The Engineering and Maintenance Department is currently developing a listing of all Master Boxes.

3. The Supervisor in Fire Prevention of the Office of Safety will maintain a complete file of Master Boxes by location and initiate a check-off procedure using reports from contractors (Boston) and Engineering and Maintenance inspections to insure compliance and follow-up on systems that are down.

C. Local Boxes

Local boxes will be inspected by the Authority's Signal Department personnel annually. Engineering and Maintenance will forward a written report to the office of Safety, c/o supervisor in Fire Prevention to insure compliance and follow-up.

D. Hydrants

All hydrants will be opened once a year, in the fall. Hydrants when out of service will be so marked. The Engineering and Maintenance Department will forward a written report to the Office of Safety, c/o Supervisor in Fire Prevention to insure compliance and follow-up.

IV. TESTS AND REPAIRS

Engineering and Maintenance will be responsible for conducting tests, inspections, repairs and signed written reports on sprinkler systems, and for tests, inspections, repairs and signed written reports on Halon Systems, fire alarms and other fire prevention equipment. The Office of safety will monitor this activity.

V. TRAINING

The Office of Safety will be responsible for coordinating the safety/training of these appointed by top management as Safety coordinators and to assist top management in their responsibility for the safety, security and welfare of those employees assigned to them.

VI. FIRE PREVENTION

All fires occurring on Authority property will be investigated by T management responsible for the vehicle, facility or right of way to determine the cause and to make recommendations to prevent recurrence. Written reports of these investigations and findings will be maintained with a copy of the report being forwarded to the Office of Safety, c/o Supervisor in Fire Prevention. Office of Safety staff will inspect all facilities and be present from time to time at tests of fire control equipment and provide assistance to various departments to correct hazards identified by them, fire insurance carriers and/or fire protection agencies.

The Supervisor in Fire Prevention of the Office of Safety will act as liaison to all fire departments in cities and towns served by the Authority and arrange for or conduct fire related training programs for Authority personnel, as well as programs for familiarizing fire department personnel with Authority equipment and property.

CLEAN AGENT FIRE EXTINGUISHING SYSTEMS

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1.0 SCOPE

This data sheet provides general information on clean agent fire extinguishing systems including guidelines for their design, installation, testing and maintenance. FM Global Property Loss Prevention Data Sheet 4-0, *Special Protection Systems*, also applies to clean agent fire extinguishing systems. See Appendix C for a listing and description, including physical properties data, for the specific clean agent extinguishants covered by this document which presently includes halocarbons and inert gases.

More detailed explanatory information on clean agent fire extinguishing systems including toxicity data and safety considerations, fire test data, fire testing protocols and enclosure integrity testing procedures is provided in NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems, 2000 Edition* and ISO 14520-1:2000, *Gaseous fire-extinguishing systems: Physical properties and system design:* Part 1: *General requirements* (other Parts covering specific agents are included under Section 4.0 REFERENCES).

Clean agent fire extinguishing systems are currently recognized for total flooding applications only. Clean agents are primarily suited for such applications given their physical properties, particularly the inert gas clean agents which are stored as compressed gases. Also, there are no established local application design criteria for clean agent extinguishing systems as exists for carbon dioxide extinguishing systems which were established through extensive testing. Carbon dioxide extinguishing systems are covered by FM Global Loss Prevention Data Sheet 4-11N.

1.1 Changes

This is the first publication of this document.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Equipment and Processes

2.1.1 Plans and Specifications

2.1.1.1 Let contracts for new installations or changes in existing systems subject to FM Global's acceptance of plans, materials, and the completed installation.

2.1.1.2 Submit final plans and calculations of new or modified systems to FM Global for review and acceptance before installation is started.

2.1.1.3 Provide final plans to scale or fully dimensioned, with sufficient detail to define clearly both the hazard and proposed system. Clearly indicate the location and sizes of piping and nozzles and their supports together with the location of the extinguishing agent supply, fire-detecting units and all auxiliary equipment. Show dampers, doors and other features in any way related to the protection of the hazard. Submit a wiring diagram if fire detection or system operations are electric. Use Approved components for the application identified by part or model number.

2.1.1.4 Prepare new drawings and calculations representing the "as-built" installation if the final installation varies from the previously submitted "final" drawings and calculations.

2.1.2 Approval of Installations (Acceptance Testing)

2.1.2.1 Verify that the clean agent fire extinguishing system has been installed in accordance with the Approved/recognized applicable system manufacturer's installation guidelines. Check that all fittings and connections necessary for the actuation of the system, particularly for pilot cylinders and interconnected storage containers or multiple banks of storage containers, have been properly arranged, secured and tightened by the system installer.

2.1.2.2 Conduct an enclosure integrity procedure (i.e., door fan test) of the protected occupancy in accordance with Appendix C of NFPA 2001. An enclosure integrity procedure in accordance with Annex E of ISO 14520 is an acceptable alternative.

The enclosure integrity procedure outlines a method to equate enclosure leakage as determined by a door fan test procedure to worst-case clean agent leakage from the protected enclosure. The calculation method provided within the procedure makes it possible to conservatively predict/estimate the hold time for a desired clean agent concentration at a specified height within the enclosure using the applicable design concentration/agent quantity required per the guidelines of 2.1.3.

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Request the contractor/installer provide certification of their training by the door fan test equipment manufacturer enabling them to properly conduct an enclosure integrity procedure in accordance with Appendix C of NFPA 2001 or Annex E of ISO 14520.

For inert gas clean agent system protected enclosures, the ELA (equivalent leakage area) determined from the door fan test may be considered as part of the recommended venting to prevent enclosure overpressurization per the system manufacturer's design guidelines.

2.1.2.3 Conduct complete system component functional tests in accordance with the applicable system manufacturer's design, installation, operation and maintenance manual.

2.1.2.4 Discharge test inert gas agent systems for final acceptance by FM Global. The design concentration should be achieved and maintained above the highest combustibles/equipment within the hazard enclosure per the guidelines of 2.1.3. Establish adequacy of venting for the hazard enclosure also.

2.1.2.5 Pneumatically test open-ended piping in a closed circuit for a period of 10 minutes at 40 psig (276 kPa). At the end of 10 minutes, the pressure drop should not exceed 20% of the test pressure. Hydrostatically test any closed-section piping to a minimum of 1.5 times the maximum working pressure for two minutes.

Note: Conduct pneumatic testing of open-ended piping prior to any planned clean agent fire extinguishing system discharge test.

2.1.2.6 Conduct a flow test using nitrogen or an inert gas on the piping network to verify that flow is continuous and that the piping and nozzles are unobstructed (i.e., a puff test). Refer to Recommendation 2.1.3.9.4 also to best assure this unobstructed flow condition.

Note: This puff test need not be conducted if the clean agent fire extinguishing system is discharge tested.

2.1.3 Installation and Design

2.1.3.1 System Design Concentrations

2.1.3.1.1 The minimum design concentration for a Class A surface fire hazard shall be the extinguishing concentration as determined by test during the system Approval evaluation times a safety factor of 1.2. Minimum design concentrations for Class C hazards shall be at least that for Class A surface fire hazards.

A 7% FM-200 (HFC-227ea) design concentration held for 10 minute is acceptable to FM Global for typical electrical/electronic equipment areas having little or no ordinary combustibles present.

A 12-14 % oxygen concentration (approximately 33-43% inert gas concentration) held for 10 minutes is acceptable to FM Global for typical electrical/electronic equipment areas having little or no ordinary combustibles present.

An 18 % FE-13 (HFC-23) design concentration held for 10 minutes is acceptable to FM Global for typical electrical/electronic equipment areas having little or no ordinary combustibles present.

2.1.3.1.2 The minimum design concentration for a Class B fuel (flammable liquid hazard) shall be the extinguishing concentration as determined by the cup burner test method per Appendix B of NFPA 2001 or Annex B of ISO 14520 times a safety factor of 1.3.

Have the clean agent system manufacturer provide the appropriate minimum design concentration verifying that the cup burner value used is in accordance with either of the above referenced test methods.

2.1.3.2 Clean Agent Quantities

2.1.3.2.1 Determine the amount of halocarbon clean agent needed to achieve the design concentration using the following equation:

$$W = \frac{V}{S}\left(\frac{C}{100 - C}\right)$$

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where:

W = weight of halocarbon clean agent [lb (kg)]

V = net volume of hazard, calculated as the gross volume minus the volume of fixed structures impervious to clean agent vapor [ft^3 (m^3)]

s = specific volume of the superheated halocarbon clean agent at 1 atmosphere and the temperature, *t [ft^3/lb (m^3/kg)]*

C = halocarbon clean agent design concentration [volume percent]

t = minimum anticipated temperature of the protected volume [°F (°C)]

Note: This equation includes an allowance for the normal leakage from a "tight" enclosure due to agent expansion.

Tables 1 though 9 also provide the weight of halocarbon clean agent needed per unit volume of enclosure to achieve the total flooding design concentration based on the above equation. These tables may be used for the applicable halocarbon clean agent rather than the referenced equation. Multiply the appropriate weight factor from the applicable table by the net enclosure volume to determine the required quantity of halocarbon clean agent.

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Table 1A. FC-2-1-8 Total Flooding Quantity (English Units)

Temp. t (°F)	Specific Vapor Volume s (ft³/lb)	Weight Requirements of Hazard Volume, W/V (lb/ft³) Design Concentration (% by Volume)							
		5	6	7	8	9	10	11	12
−30	1.6174	0.0325	0.0395	0.0465	0.0538	0.0611	0.0687	0.0764	0.0843
−20	1.6594	0.0317	0.0385	0.0454	0.0524	0.0596	0.0670	0.0745	0.0822
−10	1.7014	0.0309	0.0375	0.0442	0.0511	0.0581	0.0653	0.0726	0.0801
0	1.7434	0.0302	0.0366	0.0432	0.0499	0.0567	0.0637	0.0709	0.0782
10	1.7854	0.0295	0.0358	0.0422	0.0487	0.0554	0.0622	0.0692	0.0764
20	1.8274	0.0288	0.0349	0.0412	0.0476	0.0541	0.0608	0.0676	0.0746
30	1.8694	0.0282	0.0341	0.0405	0.0465	0.0529	0.0594	0.0661	0.0729
40	1.9114	0.0275	0.0334	0.0394	0.0455	0.0517	0.0581	0.0647	0.0713
50	1.9534	0.0269	0.0327	0.0385	0.0445	0.0506	0.0569	0.0633	0.0698
60	1.9954	0.0264	0.0320	0.0377	0.0436	0.0496	0.0557	0.0619	0.0683
70	2.0374	0.0258	0.0313	0.0369	0.0427	0.0485	0.0545	0.0607	0.0669
80	2.0794	0.0253	0.0307	0.0362	0.0418	0.0476	0.0534	0.0594	0.0656
90	2.1214	0.0248	0.0301	0.0355	0.0410	0.0466	0.0524	0.0583	0.0643
100	2.1634	0.0243	0.0295	0.0348	0.0402	0.0457	0.0514	0.0571	0.0630
110	2.2054	0.0239	0.0289	0.0341	0.0394	0.0448	0.0504	0.0560	0.0618
120	2.2474	0.0234	0.0284	0.0335	0.0387	0.0440	0.0494	0.0550	0.0607
130	2.2894	0.0230	0.0279	0.0329	0.0380	0.0432	0.0485	0.0540	0.0596
140	2.3314	0.0226	0.0274	0.0323	0.0373	0.4240	0.0477	0.0530	0.0585
150	2.3734	0.0222	0.0269	0.0317	0.0366	0.0417	0.0468	0.0521	0.0575
160	2.4154	0.0218	0.0264	0.0312	0.0360	0.0409	0.0460	0.0512	0.0565
170	2.4574	0.0214	0.0260	0.0306	0.0354	0.0402	0.0452	0.0503	0.0555
180	2.4994	0.0211	0.0255	0.0301	0.0348	0.0396	0.0445	0.0495	0.0546
190	2.5414	0.0207	0.0251	0.0296	0.0342	0.0389	0.0437	0.0486	0.0537
200	2.5834	0.0204	0.0247	0.0291	0.0337	0.0383	0.0430	0.0478	0.0528
210	2.6254	0.0200	0.0243	0.0287	0.0331	0.0377	0.0423	0.0471	0.0519
220	2.6674	0.0197	0.0239	0.0282	0.0326	0.0371	0.0417	0.0463	0.0511

W/V [agent weight requirements (lb/ft³)] = pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°F)] = the design temperature in the hazard area
s [specific volume (ft³/lb)] = specific volume of superheated FC-2-1-8 vapor can be approximated by the formula:

$$s = 1.7434 + 0.0042t$$

where t = temperature (°F)
C [concentration (%)] = volumetric concentration of FC-2-1-8 in air at the temperature indicated

Table 1A. FC-2-1-8 Total Flooding Quantity (English Units)

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Table 1B. FC-2-1-8 Total Flooding Quantity (Metric Units)

Temp. t (°C)	Specific Vapor Volume s (m^3/kg)	Weight Requirements of Hazard Volume, W/V (kg/m^3) Design Concentration (% by Volume)							
		5	6	7	8	9	10	11	12
−35	0.1008	0.5225	0.6335	0.7470	0.8630	0.9815	1.1027	1.2266	1.3533
−30	0.1031	0.5105	0.6191	0.7301	0.8434	0.9593	1.0777	1.1988	1.3226
−25	0.1054	0.4992	0.6054	0.7139	0.8247	0.9380	1.0538	1.1722	1.2933
−20	0.1078	0.4885	0.5925	0.6984	0.8068	0.9177	1.0510	1.1468	1.2653
−15	0.1101	0.4780	0.5797	0.6836	0.7897	0.8982	1.0091	1.1225	1.2384
−10	0.1124	0.4680	0.5676	0.6694	0.7733	0.8795	0.9881	1.0991	1.2127
−5	0.1148	0.4585	0.5561	0.6557	0.7576	0.8616	0.9680	1.0767	1.1880
0	0.1171	0.4494	0.5450	0.6426	0.7424	0.8444	0.9487	1.0553	1.1643
5	0.1195	0.4406	0.5343	0.6301	0.7279	0.8279	0.9301	1.0346	1.1415
10	0.1218	0.4321	0.5241	0.6180	0.7139	0.8120	0.9123	1.0148	1.1196
15	0.1241	0.4240	0.5142	0.6063	0.7006	0.7967	0.8951	0.9957	1.0985
20	0.1265	0.4162	0.5047	0.5951	0.6876	0.7820	0.8785	0.9773	1.0782
25	0.1288	0.4086	0.4955	0.5843	0.6751	0.7678	0.8626	0.9595	1.0587
30	0.1311	0.4013	0.4867	0.5739	0.6631	0.7541	0.8472	0.9424	1.0398
35	0.1335	0.3943	0.4782	0.5639	0.6514	0.7409	0.8324	0.9259	1.0216
40	0.1358	0.3875	0.4700	0.5542	0.6402	0.7282	0.8181	0.9100	1.0040
45	0.1382	0.3810	0.4620	0.5448	0.6294	0.7159	0.8042	0.8946	0.9870
50	0.1405	0.3746	0.4543	0.5357	0.6189	0.7039	0.7909	0.8797	0.9706
55	0.1428	0.3685	0.4469	0.5270	0.6088	0.6924	0.7779	0.8655	0.9547
60	0.1452	0.3626	0.4397	0.5185	0.5990	0.6813	0.7654	0.8514	0.9393
65	0.1475	0.3568	0.4327	0.5103	0.5895	0.6705	0.7533	0.8379	0.9245
70	0.1498	0.3512	0.4260	0.5023	0.5803	0.6600	0.7415	0.8248	0.9100
75	0.1522	0.3458	0.4194	0.4946	0.5714	0.6499	0.7301	0.8122	0.8961
80	0.1545	0.3406	0.4131	0.4871	0.5628	0.6401	0.7191	0.7999	0.8825
85	0.1569	0.3355	0.4069	0.4799	0.5544	0.6305	0.7084	0.7880	0.8694
90	0.1592	0.3306	0.4010	0.4728	0.5462	0.6213	0.6980	0.7764	0.8566
95	0.1615	0.3258	0.3952	0.4660	0.5383	0.6123	0.6879	0.7652	0.8442
100	0.1639	0.3212	0.3895	0.4593	0.5307	0.6035	0.6781	0.7542	0.8322

W/V [agent weight requirements (kg/m^3)] = kilograms required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°C)] = the design temperature in the hazard area
s [specific volume m^3/kg)] = specific volume of superheated FC-2-1-8 vapor can be approximated by the formula:

$$s = 0.11712 + 0.00047t$$

where t = temperature (°C)
C [concentration (%)] = volumetric concentration of FC-2-1-8 in air at the temperature indicated

Table 1B. FC-2-1-8 Total Flooding Quantity (Metric Units)

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Table 2A. FC-3-1-10 Total Flooding Quantity (English Units)

Temp. t (°F)	Specific Vapor Volume s (ft³/lb)	Weight Requirements of Hazard Volume, W/V (lb/ft³) Design Concentration (% by Volume)								
		4	5	6	7	8	9	10	11	12
−30	1.5020	0.0277	0.0350	0.0425	0.0501	0.0579	0.0658	0.0740	0.0823	0.0908
−40	1.5330	0.0272	0.0343	0.0416	0.0491	0.0567	0.0645	0.0725	0.0806	0.0890
−50	1.5640	0.0266	0.0337	0.0408	0.0481	0.0556	0.0632	0.0710	0.0790	0.0872
−60	1.5950	0.0261	0.0330	0.0400	0.0472	0.0545	0.0620	0.0697	0.0775	0.0855
−70	1.6260	0.0256	0.0324	0.0393	0.0463	0.0535	0.0608	0.0683	0.0760	0.0839
−80	1.6570	0.0251	0.0318	0.0385	0.0454	0.0525	0.0597	0.0671	0.0746	0.0823
−90	1.6880	0.0247	0.0312	0.0378	0.0446	0.0515	0.0586	0.0658	0.0732	0.0808
100	1.7190	0.0242	0.0306	0.0371	0.0438	0.0506	0.0575	0.0646	0.0719	0.0793
110	1.7500	0.0238	0.0301	0.0365	0.0430	0.0497	0.0565	0.0635	0.0706	0.0779
120	1.7810	0.0234	0.0296	0.0358	0.0423	0.0488	0.0555	0.0624	0.0694	0.0766
130	1.8120	0.0230	0.0290	0.0352	0.0415	0.0480	0.0546	0.0613	0.0682	0.0755
140	1.8430	0.0226	0.0286	0.0346	0.0408	0.0472	0.0537	0.0603	0.0671	0.0740
150	1.8740	0.0222	0.0281	0.0341	0.0402	0.0464	0.0528	0.0593	0.0660	0.0728
160	1.9050	0.0219	0.0276	0.0335	0.0395	0.0456	0.0519	0.0583	0.0649	0.0716
170	1.9360	0.0215	0.0272	0.0330	0.0389	0.0449	0.0511	0.0574	0.0638	0.0704
180	1.9670	0.0212	0.0268	0.0325	0.0383	0.0442	0.0503	0.0565	0.0628	0.0693
190	1.9980	0.0209	0.0265	0.0319	0.0377	0.0435	0.0495	0.0556	0.0619	0.0683
200	2.0290	0.0205	0.0259	0.0315	0.0371	0.0429	0.0487	0.0548	0.0609	0.0672

W/V [agent weight requirements (lb/ft³)] = pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°F)] = the design temperature in the hazard area
s [specific volume of superheated agent vapor at 1 atm and temperature, t (ft³/lb)] = specific volume of superheated FC-3-1-10 vapor can be approximated by the formula:

$$s = 1.409 + 0.0051\,t$$

where t = temperature (°F)
C [concentration (%)] = volumetric concentration of FC-3-1-10 in air at the temperature indicated

Table 2A. FC-3-1-10 Total Flooding Quantity (English Units)

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Table 2B. FC-3-1-10 Total Flooding Quantity (Metric Units)

Temp. t (°C)	Specific Vapor Volume s (m^3/kg)	Weight Requirements of Hazard Volume, W/V (kg/m^3) Design Concentration (% by Volume)							
		5	6	7	8	9	10	11	12
0	0.0941	0.5598	0.6785	0.7998	0.9240	1.0510	1.1807	1.3134	1.4491
10	0.0976	0.5395	0.6543	0.7715	0.8913	1.0138	1.1389	1.2669	1.3978
15	0.0995	0.5301	0.6429	0.7581	0.8758	0.9961	1.1191	1.2448	1.3734
20	0.1010	0.5210	0.6319	0.7451	0.8608	0.9791	1.1000	1.2235	1.3499
25	0.1027	0.5123	0.6213	0.7326	0.8464	0.9626	1.0815	1.2030	1.3272
30	0.1045	0.5038	0.6110	0.7205	0.8324	0.9467	1.0636	1.1831	1.3053
35	0.1062	0.4956	0.6011	0.7088	0.8188	0.9313	1.0463	1.1638	1.2841
40	0.1079	0.4877	0.5914	0.6974	0.8057	0.9164	1.0295	1.1452	1.2635
45	0.1097	0.4800	0.5821	0.6864	0.7930	0.9020	1.0133	1.1272	1.2436
50	0.1114	0.4725	0.5731	0.6758	0.7807	0.8880	0.9976	1.1097	1.2243
55	0.1131	0.4653	0.5643	0.6655	0.7688	0.8744	0.9824	1.0927	1.2056
60	0.1148	0.4583	0.5558	0.6555	0.7572	0.8613	0.9676	1.0763	1.1875
65	0.1166	0.4515	0.5476	0.6457	0.7460	0.8485	0.9532	1.0605	1.1699
70	0.1183	0.4449	0.5396	0.6363	0.7351	0.8361	0.9393	1.0449	1.1528
75	0.1200	0.4385	0.5318	0.6272	0.7245	0.8241	0.9258	1.0298	1.1362
80	0.1217	0.4323	0.5243	0.6183	0.7143	0.8124	0.9127	1.0152	1.1201
85	0.1235	0.4263	0.5170	0.6096	0.7045	0.8010	0.8999	1.0010	1.1044
90	0.1252	0.4204	0.5098	0.6012	0.6945	0.7900	0.8875	0.9872	1.0892
95	0.1269	0.4147	0.5029	0.5930	0.6851	0.7792	0.8754	0.9738	1.0744
100	0.1287	0.4091	0.4961	0.5850	0.6759	0.7687	0.8636	0.9607	1.0599

W/V [agent weight requirements (kg/m^3)] = kilograms required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°C)] = the design temperature in the hazard area

s [specific volume (m^3/kg)] = specific volume of superheated FC-3-1-10 vapor can be approximated by the formula:

$$s = 0.094104 + 0.000344555t$$

where t = temperature (°C)

C [concentration (%)] = volumetric concentration of FC-3-1-10 in air at the temperature indicated.

Table 2B. FC-3-10 Total Flooding Quantity (Metric Units)

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Table 3A. HCFC Blend A Total Flooding Quantity (English Units)

Temp. t (°F)	Specific Vapor Volume s (ft³/lb)	Weight Requirements of Hazard Volume, W/V (lb/ft³) Design Concentration (% by Volume) 8.6	9	10	11	12	13	14	15
–50	3.2192	0.0292	0.0307	0.0345	0.0384	0.0424	0.0464	0.0506	0.0548
–40	3.2978	0.0285	0.0300	0.0337	0.0375	0.0414	0.0455	0.0494	0.0535
–30	3.3765	0.0279	0.0293	0.0329	0.0366	0.0404	0.0443	0.0482	0.0523
–20	3.4549	0.0272	0.0286	0.0322	0.0358	0.0395	0.0433	0.0471	0.0511
–10	3.5335	0.0266	0.0280	0.0314	0.0350	0.0386	0.0423	0.0461	0.0499
0	3.6121	0.0260	0.0274	0.0308	0.0342	0.0378	0.0414	0.0451	0.0489
10	3.6906	0.0255	0.0268	0.0301	0.0335	0.0369	0.0405	0.0441	0.0478
20	3.7692	0.0250	0.0262	0.0295	0.0328	0.0362	0.0396	0.0432	0.0468
30	3.8478	0.0245	0.0257	0.0289	0.0321	0.0354	0.0388	0.0423	0.0459
40	3.9264	0.0240	0.0252	0.0283	0.0315	0.0347	0.0381	0.0415	0.0449
50	4.0049	0.0235	0.0247	0.0277	0.0309	0.0340	0.0373	0.0406	0.0441
60	4.0835	0.0230	0.0242	0.0272	0.0303	0.0334	0.0366	0.0399	0.0432
70	4.1621	0.0226	0.0238	0.0267	0.0297	0.0328	0.0360	0.0391	0.0424
80	4.2407	0.0222	0.0233	0.0262	0.0291	0.0322	0.0352	0.0384	0.0416
90	4.3192	0.0218	0.0229	0.0257	0.0286	0.0316	0.0346	0.0377	0.0409
100	4.3978	0.0214	0.0225	0.0253	0.0281	0.0310	0.0340	0.0370	0.0401
110	4.4764	0.0210	0.0221	0.0248	0.0276	0.0305	0.0334	0.0364	0.0394
120	4.5550	0.0207	0.0217	0.0244	0.0271	0.0299	0.0328	0.0357	0.0387
130	4.6336	0.0203	0.0213	0.0240	0.0267	0.0294	0.0322	0.0351	0.0381
140	4.7121	0.0200	0.0210	0.0236	0.0262	0.0289	0.0317	0.0345	0.0375
150	4.7907	0.0196	0.0206	0.0232	0.0258	0.0285	0.0312	0.0340	0.0368
160	4.8693	0.0193	0.0203	0.0228	0.0254	0.0280	0.0307	0.0334	0.0362
170	4.9479	0.0190	0.0200	0.0225	0.0250	0.0276	0.0302	0.0329	0.0357
180	5.0264	0.0187	0.0197	0.0221	0.0246	0.0271	0.0297	0.0324	0.0351
190	5.1050	0.0184	0.0194	0.0218	0.0242	0.0267	0.0293	0.0319	0.0346
200	5.1836	0.0182	0.0191	0.0214	0.0238	0.0263	0.0288	0.0314	0.0340

W/V [agent weight requirements (lb/ft³)] = pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°F)] = the design temperature in the hazard area
s [specific volume (ft³/lb)] = specific volume of superheated HCFC Blend A vapor can be approximated by the formula:

$$s = 5.612 + 0.0079t$$

where t = temperature (°F)
C [concentration (%)] = volumetric concentration of HCFC Blend A in air at the temperature indicated

Table 3A. HCFC Blend A Total Flooding Quantity (English Units)

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Table 3B. HCFC Blend A Total Flooding Quantity (Metric Units)

Temp. t (°C)	Specific Vapor Volume s (m³/kg)	Weight Requirements of Hazard Volume, W/V (kg/m³) Design Concentration (% by Volume) 8.6	9	10	11	12	13	14	15
−50	0.1971	0.4774	0.5018	0.5638	0.6271	0.6919	0.7582	0.8260	0.8954
−45	0.2015	0.4669	0.4908	0.5514	0.6134	0.6767	0.7415	0.8079	0.8758
−40	0.2059	0.4569	0.4805	0.5396	0.6002	0.6622	0.7256	0.7906	0.8570
−35	0.2103	0.4475	0.4702	0.5283	0.5876	0.6483	0.7104	0.7740	0.8390
−30	0.2148	0.4381	0.4605	0.5174	0.5755	0.6350	0.6958	0.7580	0.8217
−25	0.2192	0.4293	0.4513	0.5070	0.5639	0.6222	0.6818	0.7428	0.8052
−20	0.2236	0.4208	0.4423	0.4970	0.5528	0.6099	0.6685	0.7281	0.7893
−15	0.2280	0.4127	0.4338	0.4875	0.5421	0.5981	0.6554	0.7140	0.7740
−10	0.2324	0.4048	0.4255	0.4781	0.5318	0.5867	0.6429	0.7004	0.7593
−5	0.2368	0.3973	0.4176	0.4692	0.5219	0.5756	0.6309	0.6874	0.7451
0	0.2412	0.3900	0.4100	0.4606	0.5125	0.5652	0.6194	0.6748	0.7315
5	0.2457	0.3830	0.4026	0.4525	0.5031	0.5551	0.6083	0.6627	0.7185
10	0.2501	0.3762	0.3955	0.4445	0.4942	0.5453	0.5975	0.6510	0.7057
15	0.2545	0.3697	0.3886	0.4366	0.4856	0.5358	0.5871	0.6397	0.6934
20	0.2589	0.3634	0.3820	0.4291	0.4774	0.5267	0.5771	0.6288	0.6816
25	0.2633	0.3573	0.3756	0.4220	0.4694	0.5178	0.5675	0.6182	0.6702
30	0.2677	0.3514	0.3694	0.4150	0.4616	0.5093	0.5581	0.6080	0.6591
35	0.2722	0.3457	0.3634	0.4083	0.4541	0.5010	0.5490	0.5981	0.6484
40	0.2766	0.3402	0.3576	0.4017	0.4469	0.4930	0.5403	0.5886	0.6381
45	0.2810	0.3349	0.3520	0.3954	0.4399	0.4853	0.5318	0.5793	0.6280
50	0.2854	0.3297	0.3465	0.3893	0.4331	0.4778	0.5236	0.5704	0.6183
55	0.2898	0.3247	0.3412	0.3834	0.4265	0.4705	0.5156	0.5617	0.6089
60	0.2942	0.3198	0.3361	0.3776	0.4201	0.4634	0.5078	0.5533	0.5998
65	0.2987	0.3151	0.3312	0.3720	0.4138	0.4566	0.5003	0.5451	0.5909
70	0.3031	0.3105	0.3263	0.3666	0.4078	0.4499	0.4930	0.5371	0.5823
75	0.3075	0.3060	0.3216	0.3614	0.4020	0.4435	0.4860	0.5294	0.5739
80	0.3119	0.3017	0.3171	0.3562	0.3963	0.4372	0.4791	0.5219	0.5658
85	0.3163	0.2975	0.3127	0.3513	0.3907	0.4311	0.4724	0.5146	0.5579
90	0.3207	0.2934	0.3084	0.3464	0.3854	0.4252	0.4659	0.5076	0.5502
95	0.3251	0.2894	0.3042	0.3417	0.3801	0.4194	0.4596	0.5007	0.5427

W/V [agent weight requirements (kg/m³)] = kilograms required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°C)] = the design temperature in the hazard area
s [specific volume (m³/kg)] = specific volume of superheated HCFC Blend A vapor can be approximated by the formula:

$$s = 0.2413 + 0.00088t$$

where t = temperature (°C)
C [concentration (%)] = volumetric concentration of HCFC Blend A in air at the temperature indicated

Table 3B. HCFC Blend A Total Flooding Quantity (Metric Units)

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Table 4A. HCFC-124 Total Flooding Quantity (English Units)

Temp. t (°F)	Specific Vapor Volume s (ft^3/lb)	Weight Requirements of Hazard Volume, W/V (lb/ft^3) Design Concentration (% by Volume)							
		5	6	7	8	9	10	11	12
20	2.4419	0.0216	0.0261	0.0308	0.0356	0.0405	0.0455	0.0506	0.0558
30	2.5049	0.0210	0.0255	0.0300	0.0347	0.0395	0.0444	0.0495	0.0544
40	2.5667	0.0205	0.0249	0.0293	0.0339	0.0385	0.0433	0.0482	0.0531
50	2.6277	0.0200	0.0243	0.0286	0.0331	0.0376	0.0425	0.0470	0.0519
60	2.6878	0.0196	0.0237	0.0280	0.0324	0.0368	0.0413	0.0460	0.0507
70	2.7471	0.0192	0.0232	0.0274	0.0317	0.0360	0.0404	0.0450	0.0496
80	2.8059	0.0188	0.0227	0.0268	0.0310	0.0352	0.0396	0.0440	0.0486
90	2.8642	0.0184	0.0223	0.0263	0.0304	0.0345	0.0388	0.0432	0.0476
100	2.9219	0.0180	0.0218	0.0258	0.0298	0.0338	0.0380	0.0423	0.0467
110	2.9795	0.0177	0.0214	0.0253	0.0292	0.0332	0.0373	0.0415	0.0458
120	3.0368	0.0173	0.0210	0.0248	0.0286	0.0325	0.0366	0.0407	0.0449
130	3.0931	0.0170	0.0206	0.0243	0.0281	0.0320	0.0359	0.0400	0.0441
140	3.1494	0.0167	0.0203	0.0239	0.0276	0.0314	0.0353	0.0392	0.0433
150	3.2059	0.0164	0.0199	0.0235	0.0271	0.0308	0.0347	0.0386	0.0425
160	3.2616	0.0161	0.0196	0.0231	0.0267	0.0303	0.0341	0.0379	0.0418
170	3.3176	0.0159	0.0192	0.0227	0.0262	0.0298	0.0335	0.0373	0.0411
180	3.3729	0.0156	0.0189	0.0223	0.0258	0.0293	0.0329	0.0366	0.0404
190	3.4285	0.0154	0.0186	0.0220	0.0254	0.0288	0.0324	0.0361	0.0398
200	3.4840	0.0151	0.0183	0.0216	0.0250	0.0284	0.0319	0.0355	0.0391

W/V [agent weight requirements (lb/ft^3)] = pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°F)] = the design temperature in the hazard area

s [specific volume (ft^3/lb)] = specific volume of superheated HCFC-124 vapor can be approximated by the formula:

$$s = 2.3505 + 0.0058\,t$$

where t = temperature (°F)

C [concentration (%)] = volumetric concentration of HCFC-124 in air at the temperature indicated

Table 4A. HCFC-124 Total Flooding Quantity (English Units)

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Table 4B. HCFC-124 Total Flooding Quantity (Metric Units)

Temp. t (°C)	Specific Vapor Volume s (m^3/kg)	Weight Requirements of Hazard Volume, W/V (kg/m^3) Design Concentration (% by Volume)							
		5	6	7	8	9	10	11	12
−10	0.1500	0.3509	0.4255	0.5018	0.5797	0.6593	0.7407	0.8240	0.9091
−5	0.1536	0.3427	0.4156	0.4900	0.5661	0.6439	0.7234	0.8047	0.8878
0	0.1572	0.3348	0.4060	0.4788	0.5532	0.6291	0.7068	0.7862	0.8675
5	0.1606	0.3277	0.3974	0.4687	0.5414	0.6158	0.6919	0.7696	0.8491
10	0.1640	0.3209	0.3892	0.4590	0.5302	0.6031	0.6775	0.7536	0.8315
15	0.1674	0.3144	0.3813	0.4496	0.5195	0.5908	0.6637	0.7383	0.8146
20	0.1708	0.3081	0.3737	0.4407	0.5091	0.5790	0.6505	0.7236	0.7984
25	0.1741	0.3023	0.3666	0.4323	0.4995	0.5681	0.6382	0.7099	0.7832
30	0.1774	0.2967	0.3598	0.4245	0.4902	0.5575	0.6263	0.6967	0.7687
35	0.1806	0.2914	0.3534	0.4168	0.4815	0.5476	0.6152	0.6844	0.7551
40	0.1839	0.2862	0.3471	0.4095	0.4728	0.5378	0.6042	0.6721	0.7415
45	0.1871	0.2813	0.3412	0.4023	0.4648	0.5286	0.5939	0.6606	0.7288
50	0.1903	0.2766	0.3354	0.3955	0.4569	0.5197	0.5839	0.6495	0.7166
55	0.1934	0.2721	0.3300	0.3892	0.4496	0.5114	0.5745	0.6391	0.7051
60	0.1966	0.2677	0.3247	0.3829	0.4423	0.5031	0.5652	0.6287	0.6936
65	0.1998	0.2634	0.3195	0.3767	0.4352	0.4950	0.5561	0.6186	0.6825
70	0.2029	0.2594	0.3146	0.3710	0.4286	0.4874	0.5476	0.6091	0.6721
75	0.2061	0.2554	0.3097	0.3652	0.4219	0.4799	0.5391	0.5997	0.6616
80	0.2092	0.2516	0.3051	0.3598	0.4157	0.4728	0.5311	0.5908	0.6518
85	0.2123	0.2479	0.3007	0.3545	0.4096	0.4659	0.5234	0.5822	0.6423
90	0.2154	0.2443	0.2963	0.3494	0.4037	0.4592	0.5158	0.5738	0.6331
95	0.2185	0.2409	0.2921	0.3445	0.3980	0.4526	0.5086	0.5657	0.6241

W/V [agent weight requirements (kg/m^3)] = kilograms required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°C)] = the design temperature in the hazard area
s [specific volume (m^3/kg)] = specific volume of superheated HCFC-124 vapor can be approximated by the formula:

$$s = 0.1575 + 0.0006\,t$$

where t = temperature (°C)
C [concentration (%)] = volumetric concentration of HCFC-124 in air at the temperature indicated

Table 4B. HCFC-124 Total Flooding Quantity (Metric Units)

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Table 5A. HFC-125 Total Flooding Quantity (English Units)

Temp. t (°F)	Specific Vapor Volume s (ft³/lb)	Weight Requirements of Hazard Volume, W/V (lb/ft³) Design Concentration (% by Volume)									
		7	8	9	10	11	12	13	14	15	16
−50	2.3912	0.0515	0.0564	0.0614	0.0665	0.0517	0.0570	0.0625	0.0681	0.0738	0.0797
−40	2.4576	0.0506	0.0554	0.0602	0.0652	0.0505	0.0555	0.0608	0.0662	0.0718	0.0775
−30	2.5240	0.0298	0.0545	0.0592	0.0640	0.0490	0.0540	0.0592	0.0645	0.0699	0.0755
−20	2.5895	0.0291	0.0536	0.0582	0.0629	0.0477	0.0527	0.0577	0.0629	0.0682	0.0736
−10	2.6553	0.0285	0.0527	0.0572	0.0618	0.0465	0.0514	0.0563	0.0613	0.0665	0.0717
0	2.7205	0.0277	0.0520	0.0564	0.0608	0.0454	0.0501	0.0549	0.0598	0.0649	0.0700
10	2.7855	0.0270	0.0512	0.0555	0.0599	0.0444	0.0490	0.0536	0.0584	0.0634	0.0684
20	2.8506	0.0264	0.0505	0.0547	0.0590	0.0434	0.0478	0.0524	0.0571	0.0619	0.0668
30	2.9146	0.0258	0.0298	0.0539	0.0581	0.0424	0.0466	0.0513	0.0559	0.0605	0.0654
40	2.9780	0.0253	0.0292	0.0532	0.0575	0.0415	0.0458	0.0502	0.0546	0.0592	0.0639
50	3.0432	0.0247	0.0286	0.0525	0.0565	0.0406	0.0448	0.0491	0.0535	0.0580	0.0626
60	3.1075	0.0242	0.0280	0.0518	0.0558	0.0398	0.0439	0.0481	0.0524	0.0568	0.0613
70	3.1706	0.0237	0.0274	0.0512	0.0550	0.0390	0.0430	0.0471	0.0513	0.0557	0.0601
80	3.2342	0.0233	0.0269	0.0506	0.0544	0.0382	0.0422	0.0462	0.0503	0.0546	0.0589
90	3.2971	0.0228	0.0264	0.0500	0.0537	0.0375	0.0414	0.0453	0.0494	0.0535	0.0578
100	3.3602	0.0224	0.0259	0.0294	0.0531	0.0368	0.0406	0.0445	0.0484	0.0525	0.0567
110	3.4229	0.0220	0.0254	0.0289	0.0525	0.0361	0.0398	0.0437	0.0476	0.0516	0.0557
120	3.4855	0.0216	0.0249	0.0284	0.0519	0.0355	0.0391	0.0429	0.0467	0.0506	0.0546
130	3.5486	0.0212	0.0245	0.0279	0.0513	0.0348	0.0384	0.0421	0.0459	0.0497	0.0537
140	3.6101	0.0208	0.0241	0.0274	0.0508	0.0342	0.0378	0.0414	0.0451	0.0489	0.0528
150	3.6724	0.0205	0.0237	0.0269	0.0503	0.0337	0.0371	0.0407	0.0443	0.0481	0.0519
160	3.7341	0.0202	0.0233	0.0265	0.0298	0.0331	0.0365	0.0400	0.0436	0.0473	0.0510
170	3.7965	0.0198	0.0229	0.0261	0.0293	0.0326	0.0359	0.0394	0.0429	0.0465	0.0502
180	3.8595	0.0195	0.0225	0.0256	0.0288	0.0320	0.0353	0.0387	0.0422	0.0457	0.0494
190	3.9200	0.0192	0.0222	0.0252	0.0288	0.0315	0.0348	0.0381	0.0415	0.0450	0.0486
200	3.9825	0.0189	0.0218	0.0248	0.0279	0.0310	0.0342	0.0375	0.0409	0.0443	0.0478

W/V [agent weight requirements (lb/ft³)] = pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°F)] = the design temperature in the hazard area
s [specific volume (ft³/lb)] = specific volume of superheated HFC-125 vapor can be approximated by the formula:

$$s = 2.7280 + 0.00684t$$

where t = temperature (°F)
C [concentration (%)] = volumetric concentration of HFC-125 in air at the temperature indicated

Table 5A. HFC-125 Total Flooding Quantity (English Units)

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Table 5B. HFC-125 Total Flooding Quantity (Metric Units)

Temp. t (°C)	Specific Vapor Volume s (m^3/kg)	Weight Requirements of Hazard Volume, W/V (kg/m^3) Design Concentration (% by Volume)									
		7	8	9	10	11	12	13	14	15	16
-45	0.1497	0.5028	0.5809	0.6607	0.7422	0.8256	0.9109	0.9982	1.0874	1.1788	1.2724
-40	0.1534	0.4907	0.5669	0.6447	0.7243	0.8057	0.8889	0.9741	1.0612	1.1504	1.2417
-35	0.1572	0.4788	0.5532	0.6291	0.7068	0.7862	0.8675	0.9505	1.0356	1.1226	1.2117
-30	0.1608	0.4681	0.5408	0.6151	0.6910	0.7686	0.8480	0.9293	1.0124	1.0975	1.1846
-25	0.1645	0.4576	0.5286	0.6012	0.6754	0.7513	0.8290	0.9084	0.9896	1.0728	1.1579
-20	0.1682	0.4475	0.5170	0.5880	0.6606	0.7348	0.8107	0.8884	0.9678	1.0492	1.1324
-15	0.1719	0.4379	0.5059	0.5753	0.6464	0.7190	0.7933	0.8698	0.9470	1.0266	1.1081
-10	0.1755	0.4289	0.4955	0.5635	0.6331	0.7042	0.7770	0.8514	0.9276	1.0055	1.0853
-5	0.1791	0.4205	0.4855	0.5522	0.6204	0.6901	0.7614	0.8343	0.9089	0.9853	1.0635
0	0.1828	0.4118	0.4757	0.5410	0.6078	0.6761	0.7460	0.8174	0.8905	0.9654	1.0420
5	0.1864	0.4038	0.4665	0.5306	0.5961	0.6631	0.7316	0.8015	0.8733	0.9467	1.0219
10	0.1900	0.3962	0.4577	0.5205	0.5848	0.6505	0.7177	0.7864	0.8568	0.9288	1.0025
15	0.1935	0.3890	0.4494	0.5111	0.5742	0.6387	0.7047	0.7722	0.8413	0.9120	0.9844
20	0.1971	0.3819	0.4412	0.5018	0.5637	0.6271	0.6919	0.7581	0.8259	0.8953	0.9664
25	0.2007	0.3750	0.4333	0.4928	0.5536	0.6158	0.6794	0.7445	0.8111	0.8793	0.9491
30	0.2042	0.3686	0.4258	0.4843	0.5441	0.6053	0.6678	0.7318	0.7972	0.8642	0.9328
35	0.2078	0.3622	0.4185	0.4759	0.5347	0.5948	0.6562	0.7191	0.7834	0.8492	0.9166
40	0.2113	0.3562	0.4115	0.4681	0.5258	0.5849	0.6454	0.7072	0.7704	0.8352	0.9014
45	0.2149	0.3503	0.4046	0.4602	0.5170	0.5751	0.6345	0.6953	0.7575	0.8212	0.8863
50	0.2184	0.3446	0.3982	0.4528	0.5088	0.5659	0.6244	0.6842	0.7454	0.8080	0.8721
55	0.2219	0.3392	0.3919	0.4457	0.5007	0.5570	0.6145	0.6734	0.7336	0.7953	0.8584
60	0.2254	0.3339	0.3858	0.4388	0.4930	0.5483	0.6050	0.6629	0.7222	0.7829	0.8451
65	0.2289	0.3288	0.3799	0.4321	0.4854	0.5400	0.5957	0.6528	0.7112	0.7710	0.8321
70	0.2324	0.3239	0.3742	0.4256	0.4781	0.5318	0.5868	0.6430	0.7005	0.7593	0.8196
75	0.2358	0.3192	0.3688	0.4194	0.4712	0.5242	0.5783	0.6337	0.6904	0.7484	0.8078
80	0.2393	0.3145	0.3634	0.4133	0.4643	0.5165	0.5698	0.6244	0.6803	0.7374	0.7960
85	0.2428	0.3100	0.3581	0.4073	0.4576	0.5090	0.5616	0.6154	0.6705	0.7268	0.7845
90	0.2463	0.3056	0.3531	0.4015	0.4511	0.5018	0.5536	0.6067	0.6609	0.7165	0.7734
95	0.2498	0.3015	0.3481	0.3959	0.4448	0.4948	0.5459	0.5982	0.6517	0.7064	0.7625

W/V [agent weight requirements (kg/m^3)] = kilograms required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°C)] = the design temperature in the hazard area
s [specific volume (m^3/kg)] = specific volume of superheated HFC-125 vapor can be approximated by the formula:

$$s = 0.1825 + 0.0007t$$

where t = temperature (°C)
C [concentration (%)] = volumetric concentration of HFC-125 in air at the temperature indicated

Table 5B. HFC-125 Total Flooding Quantity (Metric Units)

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Table 6A. HFC-227ea Total Flooding Quantity (English Units)

Temp. t (°F)	Specific Vapor Volume s (ft³/lb)	Weight Requirements of Hazard Volume, W/V (lb/ft³) Design Concentration (% by Volume) 6	7	8	9	10	11	12	13	14	15
10	1.9264	0.0331	0.0391	0.0451	0.0513	0.057	0.0642	0.0708	0.0776	0.0845	0.0916
20	1.9736	0.0323	0.0381	0.0441	0.0501	0.0563	0.0626	0.0691	0.0757	0.0825	0.0894
30	2.0210	0.0316	0.0372	0.0430	0.0489	0.0550	0.0612	0.0675	0.0739	0.0805	0.0873
40	2.0678	0.0309	0.0364	0.0421	0.0478	0.0537	0.0598	0.0659	0.0723	0.0787	0.0853
50	2.1146	0.0302	0.0356	0.0411	0.0468	0.0525	0.0584	0.0645	0.0707	0.0770	0.0835
60	2.1612	0.0295	0.0348	0.0402	0.0456	0.0514	0.0572	0.0631	0.0691	0.0755	0.0817
70	2.2075	0.0289	0.0341	0.0394	0.0448	0.0505	0.0560	0.0618	0.0677	0.0737	0.0799
80	2.2538	0.0283	0.0334	0.0386	0.0439	0.0495	0.0548	0.0605	0.0663	0.0722	0.0783
90	2.2994	0.0278	0.0327	0.0378	0.0430	0.0485	0.0538	0.0593	0.0650	0.0708	0.0767
100	2.3452	0.0272	0.0321	0.0371	0.0422	0.0474	0.0527	0.0581	0.0637	0.0694	0.0752
110	2.3912	0.0267	0.0315	0.0364	0.0414	0.0465	0.0517	0.0570	0.0625	0.0681	0.0738
120	2.4366	0.0262	0.0309	0.0357	0.0406	0.0456	0.0507	0.0560	0.0615	0.0668	0.0724
130	2.4820	0.0257	0.0303	0.0350	0.0398	0.0448	0.0498	0.0549	0.0602	0.0656	0.0711
140	2.5272	0.0253	0.0298	0.0344	0.0391	0.0440	0.0489	0.0540	0.0591	0.0644	0.0698
150	2.5727	0.0248	0.0293	0.0338	0.0384	0.0432	0.0480	0.0530	0.0581	0.0633	0.0686
160	2.6171	0.0244	0.0288	0.0332	0.0378	0.0425	0.0472	0.0521	0.0571	0.0622	0.0674
170	2.6624	0.0240	0.0283	0.0327	0.0371	0.0417	0.0464	0.0512	0.0561	0.0611	0.0663
180	2.7071	0.0236	0.0278	0.0321	0.0365	0.0410	0.0457	0.0504	0.0552	0.0601	0.0652
190	2.7518	0.0232	0.0274	0.0316	0.0359	0.0404	0.0449	0.0496	0.0543	0.0592	0.0641
200	2.7964	0.0228	0.0269	0.0311	0.0354	0.0397	0.0442	0.0488	0.0535	0.0582	0.0631

W/V [agent weight requirements (lb/ft³)] = pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°F)] = the design temperature in the hazard area
s [specific volume (ft³/lb)] = specific volume of superheated HFC-227ea vapor can be approximated by the formula:

$$s = 1.555 + 0.00464t$$

where t = temperature (°F)
C [concentration (%)] = volumetric concentration of HFC-227ea in air at the temperature indicated

Table 6A. HFC-227ea Total Flooding Quantity (English Units)

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Table 6B. HFC-227ea Total Flooding Quantity (Metric Units)

Temp. t (°C)	Specific Vapor Volume s (m^3/kg)	Weight Requirements of Hazard Volume, W/V (kg/m^3) Design Concentration (% per Volume)									
		6	7	8	9	10	11	12	13	14	15
−10	0.1215	0.5254	0.6196	0.7158	0.8142	0.9147	1.0174	1.1225	1.2301	1.3401	1.4527
−5	0.1241	0.5142	0.6064	0.7005	0.7967	0.8951	0.9957	1.0985	1.2038	1.3114	1.4216
0	0.1268	0.5054	0.5936	0.6858	0.7800	0.8765	0.9748	1.0755	1.1785	1.2839	1.3918
5	0.1294	0.4952	0.5816	0.6719	0.7642	0.8586	0.9550	1.0537	1.1546	1.2579	1.3636
10	0.1320	0.4854	0.5700	0.6585	0.7490	0.8414	0.9360	1.0327	1.1316	1.2328	1.2264
15	0.1347	0.4760	0.5589	0.6457	0.7344	0.8251	0.9178	1.0126	1.1096	1.2089	1.3105
20	0.1373	0.4668	0.5483	0.6336	0.7205	0.8094	0.9004	0.9934	1.0886	1.1859	1.2856
25	0.1399	0.4564	0.5382	0.6217	0.7071	0.7944	0.8837	0.9750	1.0684	1.1640	1.2618
30	0.1425	0.4481	0.5284	0.6104	0.6943	0.7800	0.8676	0.9573	1.0490	1.1428	1.2388
35	0.1450	0.4401	0.5190	0.5996	0.6819	0.7661	0.8522	0.9402	1.0303	1.1224	1.2168
40	0.1476	0.4324	0.5099	0.5891	0.6701	0.7528	0.8374	0.9239	1.0124	1.1029	1.1956
45	0.1502	0.4250	0.5012	0.5790	0.6586	0.7399	0.8230	0.9080	0.9950	1.0840	1.1751
50	0.1527	0.4180	0.4929	0.5694	0.6476	0.7276	0.8093	0.8929	0.9784	1.0660	1.1555
55	0.1553	0.4111	0.4847	0.5600	0.6369	0.7156	0.7960	0.8782	0.9625	1.0484	1.1365
60	0.1578	0.4045	0.4770	0.5510	0.6267	0.7041	0.7832	0.8641	0.9469	1.0316	1.1183
65	0.1604	0.3980	0.4694	0.5423	0.6167	0.6929	0.7707	0.8504	0.9318	1.0152	1.1005
70	0.1629	0.3919	0.4621	0.5338	0.6072	0.6821	0.7588	0.8371	0.9173	0.9994	1.0834
75	0.1654	0.3859	0.4550	0.5257	0.5979	0.6717	0.7471	0.8243	0.9033	0.9841	1.0668
80	0.1679	0.3801	0.4482	0.5178	0.5889	0.6617	0.7360	0.8120	0.8898	0.9694	1.0509
85	0.1704	0.3745	0.4416	0.5102	0.5805	0.6519	0.7251	0.8000	0.8767	0.9551	1.0354
90	0.1730	0.3690	0.4351	0.5027	0.5717	0.6423	0.7145	0.7883	0.8638	0.9411	1.0202

W/V [agent weight requirements (kg/m^3)] = kilograms of agent per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°C)] = the design temperature in the hazard area
s [specific volume (m^3/kg)] = specific volume of superheated HFC-227ea vapor can be approximated by the formula:

$$s = 0.1269 + 0.0005\,t$$

where t = temperature (°C)
C [concentration (%)] = volumetric concentration of HFC-227ea in air at the temperature indicated

Table 6B. HFC-227ea Total Flooding Quantity (Metric Units)

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Table 7A. HFC-23 Total Flooding Quantity (English Units)

Temp. t (°F)	Specific Vapor Volume s (ft³/lb)	Weight Requirements of Hazard Volume, W/V (lb/ft³) Design Concentration (% by Volume)									
		10	12	14	15	16	17	18	20	22	24
–70	3.9573	0.0281	0.0345	0.0411	0.0446	0.0481	0.0518	0.0556	0.0632	0.0713	0.0798
–60	4.0700	0.0273	0.0335	0.0400	0.0434	0.0468	0.0503	0.0539	0.0614	0.0693	0.0776
–50	4.1817	0.0266	0.0326	0.0389	0.0422	0.0455	0.0490	0.0525	0.0598	0.0674	0.0755
–40	4.2926	0.0259	0.0318	0.0379	0.0411	0.0444	0.0477	0.0511	0.0582	0.0657	0.0736
–30	4.4029	0.0252	0.0310	0.0370	0.0401	0.0433	0.0465	0.0499	0.0568	0.0641	0.0717
–20	4.5125	0.0246	0.0302	0.0361	0.0391	0.0422	0.0454	0.0486	0.0554	0.0625	0.0700
–10	4.6216	0.0240	0.0295	0.0352	0.0382	0.0412	0.0443	0.0475	0.0541	0.0610	0.0683
0	4.7302	0.0235	0.0288	0.0344	0.0373	0.0403	0.0433	0.0464	0.0529	0.0596	0.0668
10	4.8384	0.0230	0.0282	0.0336	0.0365	0.0394	0.0423	0.0454	0.0517	0.0583	0.0653
20	4.9463	0.0225	0.0276	0.0329	0.0357	0.0385	0.0414	0.0444	0.0505	0.0570	0.0638
30	5.0538	0.0220	0.0270	0.0322	0.0349	0.0377	0.0405	0.0434	0.0495	0.0558	0.0625
40	5.1610	0.0215	0.0264	0.0315	0.0342	0.0369	0.0397	0.0425	0.0484	0.0547	0.0612
50	5.2680	0.0211	0.0259	0.0309	0.0336	0.0362	0.0389	0.0417	0.0475	0.0535	0.0599
60	5.3748	0.0207	0.0254	0.0303	0.0328	0.0354	0.0381	0.0408	0.0465	0.0525	0.0588
70	5.4814	0.0203	0.0249	0.0297	0.0322	0.0347	0.0374	0.0400	0.0456	0.0515	0.0576
80	5.5878	0.0199	0.0244	0.0291	0.0316	0.0341	0.0367	0.0393	0.0447	0.0505	0.0565
90	5.6940	0.0195	0.0239	0.0286	0.0310	0.0335	0.0360	0.0386	0.0439	0.0496	0.0555
100	5.8001	0.0192	0.0235	0.0281	0.0304	0.0328	0.0353	0.0378	0.0431	0.0486	0.0544
110	5.9061	0.0188	0.0231	0.0276	0.0299	0.0323	0.0347	0.0372	0.0423	0.0478	0.0535
120	6.0119	0.0185	0.0227	0.0271	0.0294	0.0317	0.0341	0.0365	0.0416	0.0469	0.0525
130	6.1176	0.0182	0.0223	0.0266	0.0288	0.0311	0.0335	0.0359	0.0409	0.0461	0.0516
140	6.2233	0.0179	0.0219	0.0262	0.0284	0.0306	0.0329	0.0353	0.0402	0.0453	0.0507
150	6.3289	0.0176	0.0215	0.0257	0.0279	0.0301	0.0324	0.0347	0.0395	0.0446	0.0499
160	6.4343	0.0173	0.0212	0.0253	0.0274	0.0296	0.0318	0.0341	0.0389	0.0438	0.0491
170	6.5398	0.0170	0.0209	0.0249	0.0270	0.0291	0.0313	0.0336	0.0382	0.0431	0.0483
180	6.6451	0.0167	0.0205	0.0245	0.0266	0.0287	0.0308	0.0330	0.0376	0.0424	0.0475
190	6.7504	0.0165	0.0202	0.0241	0.0261	0.0282	0.0303	0.0325	0.0370	0.0418	0.0468

W/V [agent weight requirements (lb/ft³)] = pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°F)] = the design temperature in the hazard area
s [specific volume (ft³/lb)] = specific volume of superheated HFC-23 vapor can be approximated by the formula:

$$s = 4.7250 + 0.0107\,t$$

where t = temperature (°F)
C [concentration (%)] = volumetric concentration of HFC-23 in air at the temperature indicated

Table 7A. HFC-23 Total Flooding Quantity (English Units)

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Table 7B. HFC-23 Total Flooding Quantity (Metric Units)

Temp. t (°C)	Specific Vapor Volume s (m^3/kg)	Weight Requirements of Hazard Volume, W/V (kg/m^3) Design Concentration (% by Volume)									
		10	12	14	15	16	17	18	20	22	24
−60	0.2428	0.4576	0.5616	0.6705	0.7268	0.7845	0.8436	0.9041	1.0297	1.1617	1.3006
−55	0.2492	0.4459	0.5472	0.6533	0.7081	0.7644	0.8219	0.8809	1.0032	1.1318	1.2672
−50	0.2555	0.4349	0.5337	0.6371	0.6907	0.7455	0.8016	0.8591	0.9785	1.1039	1.2360
−45	0.2617	0.4245	0.5211	0.6221	0.6743	0.7278	0.7825	0.8388	0.9553	1.0778	1.2067
−40	0.2680	0.4146	0.5088	0.6074	0.6585	0.7107	0.7643	0.8191	0.9328	1.0524	1.1783
−35	0.2742	0.4052	0.4975	0.5937	0.6436	0.6947	0.7470	0.8006	0.9117	1.0286	1.1517
−30	0.2805	0.3964	0.4865	0.5806	0.6296	0.6795	0.7307	0.7831	0.8919	1.0062	1.1266
−25	0.2868	0.3878	0.4760	0.5682	0.6160	0.6648	0.7149	0.7662	0.8726	0.9845	1.1022
−20	0.2930	0.3797	0.4660	0.5564	0.6031	0.6510	0.7000	0.7502	0.8544	0.9639	1.0793
−15	0.2967	0.3720	0.4565	0.5450	0.5908	0.6377	0.6857	0.7349	0.8370	0.9443	1.0572
−10	0.3047	0.3647	0.4475	0.5343	0.5792	0.6251	0.6722	0.7204	0.8205	0.9257	1.0364
−5	0.3106	0.3575	0.4388	0.5238	0.5678	0.6129	0.6590	0.7063	0.8044	0.9075	1.0161
0	0.3168	0.3507	0.4304	0.5139	0.5570	0.6013	0.6465	0.6929	0.7891	0.8903	0.9968
5	0.3229	0.3441	0.4223	0.5042	0.5465	0.5899	0.6343	0.6798	0.7742	0.8735	0.9780
10	0.3289	0.3378	0.4146	0.4950	0.5365	0.5791	0.6227	0.6674	0.7601	0.8576	0.9601
15	0.3349	0.3318	0.4072	0.4861	0.5269	0.5688	0.6116	0.6555	0.7465	0.8422	0.9429
20	0.3409	0.3259	0.4000	0.4775	0.5177	0.5587	0.6008	0.6439	0.7334	0.8274	0.9263
25	0.3468	0.3204	0.3932	0.4694	0.5089	0.5492	0.5906	0.6330	0.7209	0.8133	0.9106
30	0.3528	0.3149	0.3865	0.4614	0.5002	0.5399	0.5806	0.6222	0.7086	0.7995	0.8951
35	0.3588	0.3097	0.3801	0.4537	0.4918	0.5309	0.5708	0.6118	0.6968	0.7861	0.8801
40	0.3647	0.3047	0.3739	0.4464	0.4839	0.5223	0.5616	0.6019	0.6855	0.7734	0.8659
45	0.3707	0.2997	0.3679	0.4391	0.4760	0.5138	0.5525	0.5922	0.6744	0.7609	0.8519
50	0.3766	0.2950	0.3621	0.4323	0.4685	0.5058	0.5439	0.5829	0.6638	0.74489	0.8385
55	0.3826	0.2904	0.3564	0.4255	0.4612	0.4978	0.5353	0.5737	0.6534	0.7372	0.8254
60	0.3885	0.2860	0.3510	0.4190	0.4542	0.4903	0.5272	0.5650	0.6435	0.7260	0.8128
65	0.3944	0.2817	0.3457	0.4128	0.4474	0.4830	0.5193	0.5566	0.6339	0.7151	0.8007
70	0.4004	0.2775	0.3406	0.4066	0.4407	0.4757	0.5115	0.5482	0.6244	0.7044	0.7887

W/V [agent weight requirements (kg/m^3)] = kilograms required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°C)] = the design temperature in the hazard area
s [specific volume (m^3/kg)] = specific volume of superheated HFC-23 vapor can be approximated by the formula:

$$s = 0.3164 + 0.0012\,t$$

where t = temperature (°C)
C [concentration (%)] = volumetric concentration of HFC-23 in air at the temperature indicated

Table 7B. HFC-23 Total Flooding Quantity (Metric Units)

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Table 8A. HFC-236fa Total Flooding Quantity (English Units)

Temp. t (°F)	Specific Vapor Volume s (ft³/lb)	Weight Requirements of Hazard Volume, W/V (lb/ft³) Design Concentration (% by Volume) 5	6	7	8	9	10	11	12	13	14	15
30	2.2520	0.0234	0.0283	0.0334	0.0386	0.0439	0.0493	0.0549	0.0606	0.0664	0.0723	0.0784
40	2.3034	0.0228	0.0277	0.0327	0.0378	0.0429	0.0482	0.0537	0.0592	0.0649	0.0707	0.0766
50	2.3547	0.0224	0.0271	0.0320	0.0369	0.0420	0.0472	0.0525	0.0579	0.0635	0.0691	0.0749
60	2.4060	0.0219	0.0265	0.0313	0.0361	0.0411	0.0462	0.0514	0.0567	0.0621	0.0677	0.0733
70	2.4574	0.0214	0.0260	0.0306	0.0354	0.0402	0.0452	0.0503	0.0555	0.0608	0.0662	0.0718
80	2.5087	0.0210	0.0254	0.0300	0.0347	0.0394	0.0443	0.0493	0.0544	0.0596	0.0649	0.0705
90	2.5601	0.0206	0.0249	0.0294	0.0340	0.0386	0.0434	0.0483	0.0533	0.0584	0.0636	0.0689
100	2.6114	0.0202	0.0244	0.0288	0.0333	0.0379	0.0425	0.0475	0.0522	0.0572	0.0623	0.0676
110	2.6627	0.0198	0.0240	0.0283	0.0327	0.0371	0.0417	0.0464	0.0512	0.0561	0.0611	0.0663
120	2.7141	0.0194	0.0235	0.0277	0.0320	0.0364	0.0409	0.0455	0.0502	0.0551	0.0600	0.0650
130	2.7654	0.0190	0.0231	0.0272	0.0314	0.0358	0.0402	0.0447	0.0493	0.0540	0.0589	0.0638
140	2.8168	0.0187	0.0227	0.0267	0.0309	0.0351	0.0394	0.0439	0.0484	0.0530	0.0578	0.0626
150	2.8681	0.0184	0.0223	0.0262	0.0303	0.0345	0.0387	0.0431	0.0475	0.0521	0.0568	0.0615
160	2.9194	0.0180	0.0219	0.0258	0.0298	0.0339	0.0381	0.0423	0.0467	0.0512	0.0558	0.0604
170	2.9708	0.0177	0.0215	0.0253	0.0293	0.0333	0.0374	0.0416	0.0459	0.0503	0.0548	0.0594
180	3.0221	0.0174	0.0211	0.0249	0.0288	0.0327	0.0368	0.0409	0.0451	0.0494	0.0539	0.0584
190	3.0735	0.0171	0.0208	0.0245	0.0283	0.0322	0.0362	0.0402	0.0444	0.0486	0.0530	0.0574
200	3.1248	0.0168	0.0204	0.0241	0.0278	0.0317	0.0356	0.0396	0.0436	0.0478	0.0521	0.0565

W/V [agent weight requirement (lb/ft³)] = pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°F)] = the design temperature in the hazard area
s [specific volume (ft³/lb)] = specific volume of superheated HFC-236fa vapor can be approximated by the formula:

$$s = 2.098 + 0.005t$$

where t = temperature (°F)
C [concentration (%)] = volumetric concentration of HFC-236fa in air at the temperature indicated

Table 8A. HFC-236fa Total Flooding Quantity (English Units)

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Table 8B. HFC-236fa Total Flooding Quantity (Metric Units)

Temp. t (°C)	Specific Vapor Volume s (m^3/kg)	Weight Requirements of Hazard Volume, W/V (kg/m^3) Design Concentration (% by Volume)										
		5	6	7	8	9	10	11	12	13	14	15
0	0.1418	0.3725	0.4517	0.5327	0.6154	0.6999	0.7863	0.8747	0.9651	1.0575	1.1521	1.2489
5	0.1442	0.3650	0.4427	0.5220	0.6031	0.6860	0.7706	0.8572	0.9458	1.0364	1.1291	1.2240
10	0.1471	0.3579	0.4340	0.5118	0.5913	0.6725	0.7555	0.8404	0.9273	1.0161	1.1070	1.2000
15	0.1499	0.3510	0.4257	0.5020	0.5799	0.6596	0.7410	0.8243	0.9095	0.9966	1.0857	1.1769
20	0.1528	0.3444	0.4177	0.4925	0.5690	0.6472	0.7271	0.8088	0.8923	0.9778	1.0652	1.1548
25	0.1557	0.3380	0.4100	0.4834	0.5585	0.6352	0.7136	0.7938	0.8758	0.9597	1.0455	1.1334
30	0.1586	0.3319	0.4025	0.4746	0.5483	0.6237	0.7007	0.7794	0.8599	0.9423	1.0266	1.1128
35	0.1615	0.3260	0.3955	0.4662	0.5386	0.6125	0.6882	0.7655	0.8446	0.9255	1.0082	1.0930
40	0.1643	0.3203	0.3884	0.4580	0.5291	0.6018	0.6761	0.7521	0.8298	0.9092	0.9906	1.0738
45	0.1672	0.3147	0.3817	0.4501	0.5200	0.5914	0.6645	0.7391	0.8155	0.8936	0.9735	1.0553
50	0.1701	0.3094	0.3752	0.4425	0.5112	0.5814	0.6532	0.7266	0.8017	0.8785	0.9570	1.0375
55	0.1730	0.3043	0.3690	0.4351	0.5027	0.5717	0.6423	0.7145	0.7883	0.8638	0.9411	1.0202
60	0.1759	0.2993	0.3630	0.4280	0.4945	0.5624	0.6318	0.7028	0.7754	0.8497	0.9257	1.0035
65	0.1787	0.2945	0.3571	0.4211	0.4865	0.5533	0.6216	0.6915	0.7629	0.8360	0.9108	0.9873
70	0.1816	0.2898	0.3514	0.4144	0.4788	0.5445	0.6118	0.6805	0.7508	0.8227	0.8963	0.9716
75	0.1845	0.2853	0.3460	0.4080	0.4713	0.5360	0.6022	0.6699	0.7391	0.8099	0.8823	0.9566
80	0.1874	0.2809	0.3406	0.4017	0.4641	0.5278	0.5930	0.6596	0.7277	0.7974	0.8688	0.9418
85	0.1903	0.2766	0.3355	0.3956	0.4570	0.5198	0.5840	0.6496	0.7167	0.7854	0.8556	0.9275
90	0.1931	0.2725	0.3305	0.3897	0.4502	0.5121	0.5753	0.6399	0.7060	0.7737	0.8429	0.9137
95	0.1960	0.2685	0.3256	0.3840	0.4436	0.5045	0.5668	0.6305	0.6957	0.7623	0.8305	0.9003

W/V [agent weight requirements (kg/m^3)] = kilograms of agent required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°C)] = the design temperature in the hazard area
s [specific volume (m^3/kg)] = specific volume of superheated HFC-236fa vapor can be approximated by the formula:

$$s = 0.1418 + 0.0006\,t$$

where t = temperature (°C)
C [concentration (%)] = volumetric concentration of HFC-236fa in air at the temperature indicated

Table 8B. HFC-236fa Total Flooding Quantity (Metric Units)

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Table 9A. FIC-1311 Total Flooding Quantity (English Units)

Temp. t (°F)	Specific Vapor Volume s (ft³/lb)	Weight Requirements of Hazard Volume, W/V (lb/ft³) Design Concentration (% by Volume)							
		3	4	5	6	7	8	9	10
0	1.6826	0.0184	0.0248	0.0313	0.0379	0.0447	0.0517	0.0588	0.0660
10	1.7264	0.0179	0.0241	0.0305	0.0370	0.0436	0.0504	0.0573	0.0644
20	1.7708	0.0175	0.0235	0.0297	0.0361	0.0425	0.0491	0.0559	0.0628
30	1.8161	0.0170	0.0230	0.0290	0.0352	0.0415	0.0479	0.0545	0.0612
40	1.8580	0.0166	0.0224	0.0283	0.0344	0.0405	0.0468	0.0532	0.0598
50	1.9019	0.0163	0.0219	0.0277	0.0336	0.0396	0.0457	0.0520	0.0584
60	1.9457	0.0159	0.0214	0.0270	0.0328	0.0387	0.0447	0.0508	0.0571
70	1.9896	0.0155	0.0209	0.0265	0.0321	0.0378	0.0437	0.0497	0.0558
80	2.0335	0.0152	0.0205	0.0259	0.0314	0.0370	0.0428	0.0486	0.0546
90	2.0773	0.0149	0.0201	0.0253	0.0307	0.0362	0.0419	0.0476	0.0535
100	2.1212	0.0146	0.0196	0.0248	0.0301	0.0355	0.0410	0.0466	0.0524
110	2.1650	0.0143	0.0192	0.0243	0.0295	0.0348	0.0402	0.0457	0.0513
120	2.2089	0.0140	0.0189	0.0238	0.0289	0.0341	0.0394	0.0448	0.0503
130	2.2528	0.0137	0.0185	0.0234	0.0283	0.0334	0.0386	0.0439	0.0493
140	2.2966	0.0135	0.0181	0.0229	0.0278	0.0328	0.0379	0.0431	0.0484
150	2.3405	0.0132	0.0178	0.0225	0.0273	0.0322	0.0372	0.0423	0.0475
160	2.3843	0.0130	0.0175	0.0221	0.0268	0.0316	0.0366	0.0415	0.0466
170	2.4282	0.0127	0.0172	0.0217	0.0263	0.0310	0.0358	0.0407	0.0458
180	2.4721	0.0125	0.0169	0.0213	0.0258	0.0304	0.0352	0.0400	0.0449
190	2.5159	0.0123	0.0166	0.0209	0.0254	0.0299	0.0346	0.0393	0.0442
200	2.5598	0.0121	0.0163	0.0206	0.0249	0.0294	0.0340	0.0386	0.0434

W/V [agent weight requirements (lb/ft³)] = pounds of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°F)] = the design temperature in the hazard area
s [specific volume (ft³/lb)] = specific volume of superheated FIC-1311 vapor can be approximated by the formula:

$$s = 1.688 + 0.0044t$$

where t = temperature (°F)
C [concentration (%)] = volumetric concentration of FIC-1311 in air at the temperature indicated

Table 9A. FIC-1311 Total Flooding Quantity (English Units)

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Table 9B. FIC-1311 Total Flooding Quantity (Metric Units)

Temp. t (°C)	Specific Vapor Volume s (m^3/kg)	Weight Requirements of Hazard Volume, W/V (kg/m^3) Design Concentration (% by Volume)							
		3	4	5	6	7	8	9	10
−40	0.0988	0.3297	0.4442	0.5611	0.6806	0.8024	0.9270	1.0544	1.1846
−30	0.0988	0.3190	0.4217	0.5327	0.6461	0.7618	0.8801	1.0010	1.1246
−20	0.1038	0.2980	0.4014	0.5070	0.6149	0.7251	0.8377	0.9528	1.0704
−10	0.1088	0.2843	0.3830	0.4857	0.5867	0.6918	0.7992	0.9090	1.0212
0	0.1138	0.2718	0.3661	0.4625	0.5609	0.6614	0.7641	0.8691	0.9764
10	0.1188	0.2603	0.3507	0.4430	0.5373	0.6336	0.7320	0.8325	0.9353
20	0.1238	0.2498	0.3366	0.4251	0.5156	0.6080	0.7024	0.7989	0.8975
30	0.1288	0.2401	0.3235	0.4086	0.4956	0.5844	0.6751	0.7679	0.8627
40	0.1338	0.2311	0.3114	0.3934	0.4771	0.5625	0.6499	0.7392	0.8304
50	0.1388	0.2228	0.3002	0.3792	0.4599	0.5423	0.6265	0.7125	0.8005
60	0.1438	0.2151	0.2898	0.3660	0.4439	0.5234	0.6047	0.6878	0.7727
70	0.1488	0.2078	0.2800	0.3537	0.4290	0.5058	0.5844	0.6647	0.7467
80	0.1538	0.2011	0.2709	0.3422	0.4150	0.4894	0.5654	0.6431	0.7224
90	0.1588	0.1948	0.2624	0.3314	0.4020	0.4740	0.5476	0.6228	0.6997
100	0.1638	0.1888	0.2544	0.3215	0.3897	0.4595	0.5309	0.6038	0.6783

W/V [agent weight requirements (kg/m^3)] = kilograms required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$W = \frac{V}{s}\left(\frac{C}{100 - C}\right)$$

t [temperature (°C)] = the design temperature in the hazard area
s [specific volume (m^3/kg)] = specific volume of superheated FIC-1311 vapor can be approximated by the formula:

$$s = 0.1198 + 0.0005\,t$$

where t = temperature (°C)
C [concentration (%)] = volumetric concentration of FIC-1311 in air at the temperature indicated

Table 9B. FIC-1311 Total Flooding Quantity (Metric Units)

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2.1.3.2.2 Determine the amount of inert gas clean agent needed to achieve the design concentration using the following equation multiplying X by the net enclosure volume:

$$X = 2.303 \left(\frac{V_s}{S} \right) \text{Log}_{10} \left(\frac{100}{100 - C} \right)$$

where:

X = volume of inert gas added at standard conditions of 14.7 psia, 70°F (1.013 bars, 21°C) per volume of hazard space [ft^3/ft^3 (m^3/m^3)]

V_s = specific volume of inert gas clean agent at 70°F (21°C) and 14.7 psia (1.013 bar)

s = specific volume of inert gas clean agent at 1 atmosphere and temperature, t [ft^3/lb (m^3/kg)]

t = minimum anticipated temperature of the protected volume [°F (°C)]

C = inert gas design concentration [volume percent]

Note: This equation includes an allowance for agent leakage from a "tight" enclosure.

Tables 10 through 13 provide the volume factor, X, (i.e., the volume of inert gas clean agent needed per unit volume of enclosure) to achieve the total flooding design concentration based on the above equation. These tables may be used for the applicable inert gas clean agent instead of the above referenced equation. Multiply the appropriate volume factor for the applicable inert gas clean agent by the net enclosure volume to determine the required total volume of inert gas.

2.1.3.3 System Discharge Time

2.1.3.3.1 Design halocarbon clean agent systems to achieve 95% of the minimum design concentration for flame extinguishment based on a 20% safety factor within a discharge time of 10 seconds.

2.1.3.3.2 Design inert gas agent systems to achieve 95% of the minimum design concentration for flame extinguishment based on a 20% safety factor within a discharge time of 60 seconds.

Note: The applicable system discharge time period limitation is considered during the FM Approvals evaluation of any clean agent fire extinguishing system. That is, the Approved/recognized physical system/equipment arrangement limitations for pre-engineered systems is based on meeting these recommended discharge times. For engineered systems, the Approved/recognized flow calculation program is constrained to satisfy these discharge time limitations or an error message will be given for the proposed system arrangement necessitating redesign. Pre-engineered and engineered systems are further defined/described in Appendix A.

2.1.3.4 Duration of Protection

2.1.3.4.1 Maintain the agent design concentration within the protected enclosure for a minimum of 10 minutes or longer where necessary to assure effective emergency response by trained personnel.

2.1.3.5 Detection and Actuation

2.1.3.5.1 Provide automatic detection and actuation for clean agent systems using Approved fire detection devices suitable for the protected hazard or occupancy. Refer to Data Sheet 5-48, *Automatic Fire Detectors*, and the appropriate FM Global occupancy data sheet, as applicable, for guidance on detector(s)/detection system(s) selection and arrangement.

2.1.3.5.2 Provide a power supply for electrical detection and release devices independent of the power supply for the hazard area. Where this is not practical, use pneumatic or mechanical devices or provide an emergency minimum 24-hour standby capacity, battery-powered supply with automatic switchover if the primary supply fails.

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Table 10A. IG-01 Total Flooding Quantity (English Units)

Temp. t (°F)	Specific Vapor Volume s (ft³/lb)	Volume Requirements of Agent per Unit Volume of Hazard, X — Design Concentration (% by Volume)							
		34	37	40	42	47	49	58	62
-40	7.67176	0.524	0.583	0.646	0.688	0.801	0.850	1.095	1.221
-30	7.85457	0.512	0.570	0.630	0.672	0.783	0.830	1.069	1.193
-20	8.03738	0.501	0.557	0.615	0.656	0.765	0.811	1.045	1.166
-10	8.22019	0.489	0.544	0.602	0.642	0.748	0.793	1.022	1.140
0	8.40299	0.479	0.532	0.589	0.628	0.732	0.776	1.000	1.115
10	8.58580	0.469	0.521	0.576	0.614	0.716	0.759	0.978	1.091
20	8.76861	0.459	0.510	0.564	0.602	0.701	0.744	0.958	1.068
30	8.95142	0.449	0.500	0.553	0.589	0.687	0.728	0.938	1.047
40	9.13422	0.440	0.490	0.541	0.577	0.673	0.714	0.920	1.026
50	9.31703	0.432	0.480	0.531	0.566	0.660	0.700	0.902	1.006
60	9.49984	0.424	0.471	0.521	0.555	0.647	0.686	0.884	0.986
70	9.68265	0.416	0.462	0.511	0.545	0.635	0.673	0.868	0.968
80	9.86545	0.408	0.453	0.501	0.535	0.623	0.661	0.851	0.950
90	10.04826	0.400	0.445	0.492	0.525	0.612	0.649	0.836	0.932
100	10.23107	0.393	0.437	0.483	0.516	0.601	0.637	0.821	0.916
110	10.41988	0.386	0.430	0.475	0.506	0.590	0.626	0.807	0.900
120	10.59668	0.380	0.422	0.467	0.498	0.580	0.615	0.795	0.884
130	10.77949	0.373	0.415	0.459	0.489	0.570	0.605	0.779	0.869
140	10.96230	0.367	0.408	0.451	0.481	0.561	0.595	0.766	0.855
150	11.14511	0.361	0.401	0.444	0.473	0.552	0.585	0.754	0.841
160	11.32791	0.355	0.395	0.437	0.466	0.543	0.576	0.742	0.827
170	11.51072	0.350	0.389	0.430	0.458	0.534	0.566	0.730	0.814
180	11.69353	0.344	0.383	0.425	0.451	0.526	0.558	0.718	0.801
190	11.87634	0.339	0.377	0.416	0.444	0.518	0.549	0.707	0.789
200	12.05914	0.334	0.371	0.410	0.437	0.510	0.541	0.697	0.777

X [agent volume requirements (ft³/ft³)] = volume of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{V_s}{s}\right) \times \text{Log}_{10}\left(\frac{100}{100-C}\right) = \left(\frac{V_s}{s}\right) \times \ln\left(\frac{100}{100-C}\right)$$

t [temperature (°F)] = the design temperature in the hazard area
s [specific volume (ft³/lb)] = specific volume of superheated IG-01 vapor can be approximated by the formula:

$$s = 8.514 + 0.0185t$$

where t = temperature (°F)
C [concentration (%)] = volumetric concentration of IG-01 in air at the temperature indicated

V_s [specific volume (ft³/lb)] = specific volume of IG-01 at 70°F (ft³/lb) = 9.683 ft³/lb

Table 10A. IG-01 Total Flooding Quantity (English Units)

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Table 10B. IG-01 Total Flooding Quantity (Metric Units)

Temp. t (°C)	Specific Vapor Volume s (m^3/kg)	Volume Requirements of Agent per Unit Volume of Hazard, X — Design Concentration (% by Volume)							
		34	37	40	42	47	49	58	62
-20	0.5201	0.4812	0.5350	0.5915	0.6308	0.7352	0.7797	1.0046	1.1205
-10	0.5406	0.4629	0.5147	0.5691	0.6068	0.7073	0.7501	0.9664	1.0779
0	0.5612	0.4459	0.4959	0.5482	0.5846	0.6814	0.7226	0.9310	1.0384
10	0.5817	0.4302	0.4784	0.5289	0.5640	0.6575	0.6971	0.8981	1.0018
15	0.5920	0.4227	0.4701	0.5197	0.5542	0.6459	0.6850	0.8828	0.9844
20	0.6025	0.4155	0.4620	0.5108	0.5447	0.6349	0.6733	0.8675	0.9676
30	0.6228	0.4018	0.4468	0.4940	0.5268	0.6139	0.6511	0.8389	0.9367
35	0.6331	0.3953	0.4395	0.4860	0.5182	0.6040	0.6406	0.8253	0.9205
40	0.6434	0.3890	0.4325	0.4782	0.5099	0.5945	0.0305	0.8121	0.9058
50	0.6639	0.3769	0.4191	0.4634	0.4942	0.5759	0.6108	0.7870	0.8778
60	0.6845	0.3656	0.4066	0.4496	0.4795	0.5587	0.5925	0.7633	0.8514
70	0.7050	0.3550	0.3947	0.4364	0.4654	0.5424	0.5752	0.7411	0.8200
80	0.7256	0.3449	0.3835	0.4240	0.4522	0.5270	0.5589	0.7201	0.8032
90	0.7461	0.3354	0.3730	0.4124	0.4397	0.5125	0.5436	0.7003	0.7811
100	0.7666	0.3264	0.3630	0.4013	0.4270	0.4988	0.5290	0.6815	0.7601
110	0.7872	0.3179	0.3535	0.3908	0.4168	0.4857	0.5152	0.6637	0.7405
120	0.8077	0.3098	0.3445	0.3809	0.4062	0.4734	0.5021	0.6468	0.7215

X [agent volume requirements (m^3/m^3)] = volume of agent required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{V_s}{s}\right) \times \text{Log}_{10}\left(\frac{100}{100-C}\right) = \left(\frac{V_s}{s}\right) \times \ln\left(\frac{100}{100-C}\right)$$

t [temperature (°C)] = the design temperature in the hazard area
s [specific volume (m^3/kg)] = specific volume of superheated IG-01 vapor can be approximated by the formula:

$$s = 0.5685 + 0.00208t$$

where t = temperature (°C)
C [concentration (%)] = volumetric concentration of IG-01 in air at the temperature indicated

V_s [specific volume (m^3/kg)] = specific volume of IG-01 at 21°C (m^3/kg) = 0.604 m^3/kg

Table 10B. IG-01 Total Flooding Quantity (Metric Units)

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Table 11A. IG-100 Total Flooding Quantity (English Units)

Temp. t (°F)[c]	Specific Vapor Volume s (ft³/lb)[d]	Volume Requirements of Agent per Unit Volume of Hazard, X — Design Concentration (% by Volume)							
		34	37	40	42	47	49	58	62
−40	10.934	0.522	0.581	0.642	0.685	0.798	0.847	1.091	1.216
−30	11.195	0.510	0.567	0.627	0.669	0.780	0.827	1.065	1.188
−20	11.455	0.499	0.554	0.613	0.654	0.762	0.808	1.041	1.161
−10	11.716	0.488	0.542	0.599	0.639	0.745	0.790	1.018	1.135
0	11.976	0.477	0.530	0.586	0.625	0.729	0.773	0.996	1.111
10	12.237	0.467	0.519	0.574	0.612	0.713	0.756	0.975	1.087
20	12.497	0.457	0.508	0.562	0.599	0.698	0.741	0.954	1.064
30	12.758	0.448	0.498	0.550	0.587	0.684	0.726	0.935	1.043
40	13.018	0.439	0.488	0.539	0.575	0.670	0.711	0.916	1.022
50	13.279	0.430	0.478	0.529	0.564	0.657	0.697	0.898	1.002
60	13.540	0.422	0.469	0.519	0.553	0.645	0.684	0.881	0.982
70	13.800	0.414	0.460	0.509	0.543	0.632	0.671	0.864	0.964
80	14.061	0.406	0.452	0.499	0.533	0.621	0.658	0.848	0.946
90	14.321	0.399	0.444	0.490	0.523	0.609	0.646	0.833	0.929
100	14.582	0.392	0.436	0.482	0.514	0.599	0.635	0.818	0.912
110	14.842	0.385	0.428	0.473	0.505	0.588	0.624	0.803	0.896
120	15.103	0.378	0.421	0.465	0.496	0.578	0.613	0.790	0.881
130	15.363	0.372	0.413	0.457	0.487	0.568	0.602	0.776	0.866
140	15.624	0.366	0.407	0.449	0.479	0.559	0.592	0.763	0.851
150	15.886	0.360	0.400	0.442	0.471	0.549	0.583	0.751	0.837
160	16.145	0.354	0.393	0.435	0.464	0.541	0.573	0.739	0.824
170	16.406	0.348	0.387	0.428	0.456	0.532	0.564	0.727	0.811
180	16.666	0.343	0.381	0.421	0.449	0.524	0.555	0.716	0.798
190	16.927	0.337	0.375	0.415	0.442	0.516	0.547	0.705	0.786
200	17.187	0.332	0.370	0.409	0.436	0.508	0.539	0.694	0.774

X [agent volume requirements (ft³/ft³)] = volume of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{V_s}{s}\right) \times \text{Log}_{10}\left(\frac{100}{100 - C}\right) = \left(\frac{V_s}{s}\right) \times \ln\left(\frac{100}{100 - C}\right)$$

t [temperature (°F)] = the design temperature in the hazard area

s [specific volume (ft³/lb)] = specific volume of superheated IG-100 vapor can be approximated by the formula:

$$s = 11.976 + 0.02606t$$

where t = temperature (°F)

C [concentration (%)] = volumetric concentration of IG-100 in air at the temperature indicated

V_s [specific volume (ft³/lb)] = specific volume of IG-100 at 70°F (ft³/lb) = 13.800 ft³/lb

Table 11A. IG-100 Total Flooding Quantity (English Units)

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Table 11B. IG-100 Total Flooding Quantity (Metric Units)

Temp. t (°C)	Specific Vapor Volume s (m^3/kg)	Volume Requirements of Agent per Unit Volume of Hazard, X Design Concentration (% by Volume)							
		34	37	40	42	47	49	58	62
-40	0.6826	0.5225	0.5809	0.6425	0.6849	0.7983	0.8466	1.0908	1.2166
-30	0.7119	0.5009	0.5570	0.6159	0.6567	0.7654	0.8118	1.0459	1.1665
-20	0.7412	0.4811	0.5350	0.5915	0.6308	0.7352	0.7797	1.0045	1.1204
-10	0.7704	0.4629	0.5147	0.5691	0.6069	0.7073	0.7501	0.9664	1.0779
0	0.7997	0.4459	0.4959	0.5482	0.5846	0.6814	0.7227	0.9310	1.0384
10	0.8290	0.4302	0.4783	0.5289	0.5640	0.6575	0.6971	0.8981	1.0017
20	0.8582	0.4155	0.4621	0.5109	0.5448	0.6349	0.6734	0.8676	0.9677
30	0.8875	0.4018	0.4468	0.4940	0.5268	0.6140	0.6512	0.8389	0.9357
40	0.9168	0.3890	0.4325	0.4782	0.5100	0.5945	0.6304	0.8121	0.9058
50	0.9461	0.3769	0.4191	0.4634	0.4942	0.5759	0.6108	0.7870	0.8778
60	0.9753	0.3657	0.4066	0.4495	0.4794	0.5587	0.5925	0.7634	0.8515
70	1.0046	0.3550	0.3947	0.4364	0.4654	0.5424	0.5753	0.7411	0.8266
80	1.0339	0.3449	0.3835	0.4241	0.4522	0.5270	0.5590	0.7201	0.8032
90	1.0631	0.3355	0.3730	0.4124	0.4398	0.5126	0.5436	0.7004	0.7812
100	1.0924	0.3265	0.3630	0.4013	0.4280	0.4988	0.5290	0.6816	0.7602

X [agent volume requirements (m^3/m^3)] = volume of agent required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{V_s}{s}\right) \times \text{Log}_{10}\left(\frac{100}{100-C}\right) = \left(\frac{V_s}{s}\right) \times \ln\left(\frac{100}{100-C}\right)$$

t [temperature (°C)] = the design temperature in the hazard area
s [specific volume (m^3/kg)] = specific volume of superheated IG-100 vapor can be approximated by the formula:

$$s = 0.7997 + 0.00293t$$

where t = temperature (°C)
C [concentration (%)] = volumetric concentration of IG-100 in air at the temperature indicated
V_s [specific volume (m^3/kg)] = specific volume of IG-100 at 21°C (m^3/kg) = 0.861 m^3/kg

Table 11B. IG-100 Total Flooding Quantity (Metric Units)

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Table 12A. IG-541 Total Flooding Quantity (English Units)

Temp. t (°F)	Specific Vapor Volume s (ft³/lb)	Volume Requirements of Agent per Unit Volume of Hazard, X — Design Concentration (% by Volume)							
		34	38	42	46	50	54	58	62
−40	9.001	0.524	0.605	0.686	0.802	0.873	0.977	1.096	1.218
−30	9.215	0.513	0.590	0.672	0.760	0.855	0.958	1.070	1.194
−20	9.429	0.501	0.576	0.657	0.743	0.836	0.936	1.046	1.166
−10	9.644	0.490	0.563	0.642	0.726	0.817	0.915	1.022	1.140
0	9.858	0.479	0.551	0.628	0.710	0.799	0.895	1.000	1.116
10	10.072	0.469	0.539	0.615	0.695	0.782	0.876	0.979	1.092
20	10.286	0.459	0.528	0.602	0.681	0.766	0.858	0.958	1.069
30	10.501	0.450	0.517	0.590	0.667	0.750	0.840	0.939	1.047
40	10.715	0.441	0.507	0.578	0.653	0.735	0.824	0.920	1.026
50	10.929	0.432	0.497	0.566	0.641	0.721	0.807	0.902	1.006
60	11.144	0.424	0.487	0.555	0.628	0.707	0.792	0.885	0.987
70	11.358	0.416	0.478	0.545	0.616	0.693	0.777	0.868	0.968
80	11.572	0.408	0.469	0.535	0.605	0.681	0.762	0.852	0.950
90	11.787	0.401	0.461	0.525	0.594	0.668	0.749	0.836	0.933
100	12.001	0.393	0.453	0.516	0.583	0.656	0.735	0.821	0.916
110	12.215	0.386	0.445	0.507	0.573	0.645	0.722	0.807	0.900
120	12.429	0.380	0.437	0.498	0.563	0.634	0.710	0.793	0.884
130	12.644	0.373	0.430	0.489	0.554	0.623	0.698	0.779	0.869
140	12.858	0.367	0.422	0.481	0.544	0.612	0.686	0.766	0.855
150	13.072	0.361	0.415	0.473	0.535	0.602	0.675	0.754	0.841
160	13.287	0.355	0.409	0.466	0.527	0.593	0.664	0.742	0.827
170	13.501	0.350	0.402	0.458	0.518	0.583	0.653	0.730	0.814
180	13.715	0.344	0.396	0.451	0.510	0.574	0.643	0.718	0.801
190	13.930	0.339	0.390	0.444	0.502	0.565	0.633	0.707	0.789
100	14.144	0.334	0.384	0.437	0.495	0.557	0.624	0.697	0.777

X [agent volume requirements (ft^3/ft^3) = volume of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{V_s}{s}\right) \times \text{Log}_{10}\left(\frac{100}{100-C}\right) = \left(\frac{V_s}{s}\right) \times \ln\left(\frac{100}{100-C}\right)$$

t [temperature (°F)] = the design temperature in the hazard area

s [specific volume (ft^3/lb)] = specific volume of superheated IG-541 vapor can be approximated by the formula:

$$s = 9.8579 + 0.02143t$$

where t = temperature (°F)

C [concentration (%)] = volumetric concentration of IG-541 in air at the temperature indicated

V_s [specific volume (ft^3/lb)] = specific volume of IG-541 at 70°F (ft^3/lb) = 11.358 ft^3/lb

Table 12A. IG-541 Total Flooding Quantity (English Units)

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Table 12B. IG-541 Total Flooding Quantity (Metric Units)

Temp. t (°C)	Specific Vapor Volume s (m³/kg)	Volume Requirements of Agent per Unit Volume of Hazard, X — Design Concentration (% by Volume)							
		34	38	42	46	50	54	58	62
−40	0.562	0.524	0.603	0.686	0.802	0.873	0.977	1.093	1.218
−30	0.591	0.502	0.578	0.657	0.769	0.837	0.936	1.048	1.167
−20	0.611	0.482	0.555	0.631	0.738	0.803	0.899	1.006	1.121
−10	0.635	0.464	0.534	0.608	0.711	0.774	0.866	0.969	1.080
0	0.659	0.447	0.515	0.568	0.685	0.745	0.834	0.933	1.040
10	0.683	0.431	0.496	0.565	0.660	0.719	0.804	0.900	1.003
20	0.707	0.417	0.480	0.546	0.639	0.695	0.778	0.870	0.970
30	0.731	0.403	0.464	0.528	0.617	0.672	0.752	0.841	0.937
40	0.755	0.390	0.449	0.511	0.597	0.650	0.727	0.814	0.907
50	0.780	0.378	0.435	0.495	0.579	0.630	0.706	0.788	0.878
60	0.804	0.356	0.422	0.480	0.562	0.611	0.684	0.766	0.853
70	0.828	0.346	0.410	0.466	0.545	0.593	0.664	0.743	0.828
80	0.852	0.337	0.398	0.453	0.530	0.576	0.645	0.722	0.804
90	0.876	0.337	0.387	0.441	0.516	0.561	0.628	0.702	0.783
100	0.900	0.328	0.377	0.429	0.502	0.546	0.611	0.684	0.762

X [agent volume requirements (m³/m³) = volume of agent required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{V_s}{s}\right) \times \text{Log}_{10}\left(\frac{100}{100-C}\right) = \left(\frac{V_s}{s}\right) \times \ln\left(\frac{100}{100-C}\right)$$

t [temperature (°C)] = the design temperature in the hazard area
s [specific volume (m³/kg)] = specific volume of superheated IG-541 vapor can be approximated by the formula:

$$s = 0.65799 + 0.00239t$$

where t = temperature (°C)
C [concentration (%)] = volumetric concentration of IG-541 in air at the temperature indicated
V_s [specific volume (m³/kg)] = specific volume of IG-541 at 21°C (m³/kg) = 0.710 m³/kg

Table 12B. IG-541 Total Flooding Quantity (Metric Units)

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Table 13A. IG-55 Total Flooding Quantity (English Units)

Temp. t (°F)	Specific Vapor Volume s (ft³/lb)	Volume Requirements of Agent per Unit Volume of Hazard, X — Design Concentration (% by Volume)							
		34	38	42	46	50	54	58	62
−40	9.02108	0.524	0.605	0.688	0.778	0.875	0.980	1.095	1.221
−30	9.23603	0.512	0.589	0.672	0.760	0.854	0.957	1.069	1.193
−20	9.45099	0.501	0.576	0.656	0.742	0.835	0.936	1.045	1.166
−10	9.66594	0.489	0.563	0.642	0.726	0.816	0.915	1.022	1.140
0	9.88090	0.479	0.551	0.628	0.710	0.799	0.895	1.000	1.115
10	10.09586	0.469	0.539	0.614	0.695	0.782	0.876	0.978	1.091
20	10.31081	0.459	0.528	0.602	0.680	0.765	0.857	0.956	1.068
30	10.52577	0.449	0.517	0.589	0.667	0.750	0.840	0.938	1.047
40	10.74073	0.440	0.507	0.577	0.653	0.735	0.823	0.920	1.026
50	10.95568	0.432	0.497	0.566	0.640	0.720	0.807	0.902	1.006
60	11.17064	0.424	0.487	0.555	0.628	0.706	0.791	0.884	0.986
70	11.38560	0.416	0.478	0.545	0.616	0.693	0.777	0.868	0.968
80	11.60055	0.408	0.469	0.535	0.605	0.680	0.762	0.851	0.950
90	11.81551	0.400	0.461	0.525	0.594	0.668	0.748	0.836	0.932
100	12.03046	0.393	0.452	0.516	0.583	0.656	0.735	0.821	0.916
110	12.24542	0.386	0.444	0.506	0.573	0.644	0.722	0.807	0.900
120	12.46038	0.380	0.437	0.498	0.563	0.633	0.710	0.793	0.884
130	12.67533	0.373	0.429	0.489	0.555	0.623	0.698	0.779	0.869
140	12.89029	0.367	0.422	0.481	0.544	0.612	0.686	0.766	0.855
150	13.10525	0.361	0.415	0.473	0.535	0.602	0.675	0.754	0.841
160	13.32020	0.356	0.409	0.466	0527	0.592	0.664	0.742	0.827
170	13.53516	0.350	0.402	0.458	0.518	0.583	0.653	0.730	0.814
180	13.75012	0.344	0.396	0.451	0.510	0.574	0.643	0.718	0.801
190	13.96507	0.339	0.390	0.444	0.502	0.565	0.633	0.707	0.789
200	14.18003	0.334	0.384	0.437	0.495	0.557	0.623	0.697	0.777

X [agent volume requirements (ft^3/ft^3)] = volume of agent required per cubic foot of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{V_s}{s}\right) \times \text{Log}_{10}\left(\frac{100}{100 - C}\right) = \left(\frac{V_s}{s}\right) \times \ln\left(\frac{100}{100 - C}\right)$$

t [temperature (°F)] = the design temperature in the hazard area
s [specific volume (ft^3/lb)] = specific volume of superheated IG-55 vapor can be approximated by the formula:

$$s = 9.8889 + 0.0215t$$

where t = temperature (°F)
C [concentration (%)] = volumetric concentration of IG-55 in air at the temperature indicated
V_s [specific volume (ft^3/lb)] = specific volume of IG-55 at 70°F (ft^3/lb) = 11.386 ft^3/lb

Table 13A. IG-55 Total Flooding Quantity (English Units)

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Table 13B. IG-55 Total Flooding Quantity (Metric Units)

Temp. t (°C)	Specific Vapor Volume s (m^3/kg)	Volume Requirements of Agent per Unit Volume of Hazard, X — Design Concentration (% by Volume)							
		34	38	42	46	50	54	58	62
-40	0.56317	0.524	0.603	0.688	0.778	0.875	0.980	1.095	1.221
-35	0.56324	0.515	0.591	0.673	0.761	0.856	0.959	1.072	1.196
-30	0.58732	0.503	0.579	0.659	0.746	0.839	0.940	1.050	1.171
-25	0.59940	0.493	0.567	0.646	0.731	0.822	0.921	1.029	1.147
-20	0.61148	0.483	0.556	0.633	0.716	0.806	0.903	1.008	1.125
-15	0.62355	0.474	0.545	0.621	0.702	0.790	0.885	0.989	1.103
-10	0.63563	0.465	0.535	0.609	0.689	0.775	0.868	0.970	1.082
-5	0.64771	0.456	0.525	0.598	0.676	0.761	0.852	0.952	1.062
0	0.65979	0.448	0.515	0.587	0.664	0.747	0.837	0.935	1.042
5	0.67186	0.440	0.506	0.576	0.652	0.733	0.822	0.918	1.024
10	0.68394	0.432	0.497	0.566	0.640	0.720	0.807	0.902	1.006
15	0.69602	0.424	0.488	0.556	0.629	0.708	0.793	0.886	0.988
20	0.70810	0.417	0.480	0.547	0.619	0.696	0.779	0.871	0.971
25	0.72017	0.410	0.472	0.538	0.608	0.684	0.766	0.856	0.955
30	0.73225	0.403	0.464	0.529	0.598	0.673	0.754	0.842	0.939
35	0.74433	0.397	0.456	0.520	0.588	0.662	0.742	0.828	0.924
40	0.75641	0.390	0.449	0.512	0.579	0.651	0.730	0.815	0.909
45	0.76848	0.384	0.442	0.504	0.570	0.641	0.718	0.802	0.895
50	0.78056	0.378	0.435	0.496	0.561	0.631	0.707	0.790	0.881
55	0.79264	0.373	0.429	0.488	0.553	0.622	0.696	0.778	0.868
60	0.80471	0.367	0.422	0.481	0.544	0.612	0.686	0.766	0.855
65	0.81679	0.362	0.416	0.474	0.536	0.603	0.676	0.755	0.842
70	0.82887	0.356	0.410	0.467	0.528	0.594	0.666	0.744	0.830
75	0.84095	0.351	0.404	0.460	0.521	0.586	0.656	0.733	0.818
80	0.85302	0.346	0.398	0.454	0.513	0.578	0.647	0.723	0.806
85	0.86510	0.341	0.393	0.448	0.506	0.569	0.638	0.713	0.795
90	0.87718	0.337	0.387	0.441	0.499	0.562	0.629	0.703	0.784
95	0.88926	0.332	0.382	0.435	0.493	0.554	0.621	0.693	0.773
100	0.90133	0.328	0.377	0.430	0.486	0.547	0.612	0.684	0.763

X [agent volume requirements (m^3/m^3)] = volume of agent required per cubic meter of protected volume to produce indicated concentration at temperature specified.

$$X = 2.303 \times \left(\frac{V_s}{s}\right) \times \text{Log}_{10}\left(\frac{100}{100 - C}\right) = \left(\frac{V_s}{s}\right) \times \ln\left(\frac{100}{100 - C}\right)$$

t [temperature (°C)] = the design temperature in the hazard area
s [specific volume (m^3/kg)] = specific volume of superheated IG-55 vapor can be approximated by the formula:

$$s = 0.6598 + 0.00242t$$

where t = temperature (°C)
C [concentration (%)] = volumetric concentration of IG-55 in air at the temperature indicated

V_s [specific volume (m^3/kg)] = specific volume of IG-55 at 21°C (m^3/kg) = 0.711 m^3/kg

Table 13B. IG-55 Total Flooding Quantity (Metric Units)

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Where a clean agent fire extinguishing system is the sole or recommended protection for valuable and important occupancies, provide an alternate power supply for any electrically operated detection and actuation system. An emergency battery-powered supply, with automatic switchover if the primary supply fails, as required for an Approved control panel is an acceptable alternate power supply. Locate the electrical power supply so it is not exposed by the protected area.

2.1.3.5.3 Locate and protect wiring, cables and tubing to avoid mechanical damage. Install wiring and cables in conduit. Also locate tubing in vulnerable locations in conduit or equivalent. Conduit is not needed for short lengths of cables or tubing near detectors and controls. Do not install wiring or tubing used as detectors in conduit.

2.1.3.5.4 Where manual bypass switches are provided to prevent accidental discharge of a a clean agent fire extinguishing system especially during testing or servicing of the system; provide "keyed lock-out" devices located at the control panel. Arrange these devices so they do not disable the alarm circuit. Establish and follow written impairment procedures. Preferably, leave the key(s) under the control of a responsible management or fire protection person.

2.1.3.5.5 Provide a readily accessible normal manual and emergency manual means of operation, preferably mechanical, for clean agent fire extinguishing systems.

2.1.3.6 Operating Devices

2.1.3.6.1 Locate, install or suitably protect all operating devices so that they are not subject to mechanical, chemical, or other damage that would render them inoperative. Operating devices include all clean agent releasing devices or valves, discharge controls and equipment shutdowns/interlocks necessary for successful performance of the system.

Exception: Power interlocks, although preferred to minimize the potential for sustained ignition and agent decomposition (in the case of halocarbon clean agents), are not required for critical electronic equipment areas (e.g., computer rooms, process control rooms, telecommunication offices, etc.) where this will cause operating problems.

Abort switches though generally not recommended are acceptable to FM Global. Where provided, use abort switches that requires constant manual pressure to cause abort and located them within the protected area near the means of egress from the protected area. Where activation of more than one detector is necessary for system actuation, arrange the abort switch to prevent discharge only if operated before the second detector activates. In addition, operation of an abort switch should not recycle any time delays.

2.1.3.6.2 Identify all controls as to function, area controlled, and operating instructions.

2.1.3.7 Alarms and Supervisory Devices

2.1.3.7.1 Provide a pre-discharge alarm and time delay sufficient to allow personnel evacuation prior to discharge. Limit the time delay to 30 seconds maximum after the appropriate detection signal(s) for system actuation have been received.

System discharge can be startling and avoiding unnecessary exposure to extinguishants is desirable even when the design concentration is below the No Observed Adverse Effects Level (NOAEL).

2.1.3.7.2 When a clean agent system is is the sole or recommended protection for an important occupancy or equipment, supervise the detection devices and circuits through an Approved proprietary system or central station. Provide trouble alarms and discharge alarms distinctive from each other, to sound at a constantly attended location.

2.1.3.8 Supply of Extinguishing Agent

2.1.3.8.1 Provide an in-service supply of extinguishing agent adequate for at least the largest single hazard or group of hazards to be protected simultaneously.

2.1.3.8.2 Provide a reserve supply equivalent to the required in-service supply unless available from an outside source within 24 hours. Reserve supplies are necessary to permit prompt restoration of the system after a discharge, to minimize interruption of the process and the interval of impaired protection.

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2.1.3.8.3 Where two or more hazards are protected by a single supply through selector valves, connect the reserve supply to the distribution piping. Provide a switchover arrangement to permit actuation by the normal means (e.g., a manually actuated main/reserve switch at the control panel).

2.1.3.8.4 Provide a connected reserve where the clean agent system is the sole protection for valuable and important occupancies unless protection can be fully restored within 24 hours, occupancies are constantly attended and written impairment procedures have been established.

2.1.3.8.5 Preferably locate agent storage containers outside the hazard area to minimize fire exposure and provide ready accessibility for actuation, inspection and maintenance. Storage containers may be located within the hazard area for low frequency/fire severity areas (e.g., computer or control rooms) provided the wiring from the control panel to the storage containers is mineral-insulated metal-sheathed cable, Type MI or at least 212°F (100°C) rated in conduit.

2.1.3.8.6 Locate or arrange agent storage containers such that storage temperatures are maintained within the system manufacturer's listed limits.

2.1.3.9 Piping

2.1.3.9.1 Provide system piping of noncombustible material having physical and chemical characteristics such that its integrity under stress can be predicted with reliability. Calculate the required piping wall thickness in accordance with ASME B31.1, *Power Piping Code*, or other relevant national standard. Use a pressure for this calculation not less than the greater of either of the following values:

a) The normal charging pressure in the agent container at 70°F (21°C), or

b) Eighty percent of the maximum pressure in the agent container at the maximum storage temperature of not less than 130°F (54°C) using the equipment manufacturer's maximum allowable fill density, if applicable.

Exception: Flexible pipe, tubing or hose which is part of an Approved system.

2.1.3.9.2 Do not use cast iron pipe, steel pipe conforming to ASTM A-120, *Specification for Seamless Carbon Steel Pipe for High Temperature Service*, or nonmetallic pipe.

2.1.3.9.3 Provide special corrosion-resistant materials or coatings for piping located in corrosive environments. At a minimum, use galvanized piping, inside and out, where exposed to varying atmospheric conditions.

2.1.3.9.4 Avoid obstructions in piping from foreign materials or faulty fabrication. Ream and clean piping before assembly. After assembly, blow out the entire system before nozzles or discharge devices are installed.

2.1.3.10 Nozzles

2.1.3.10.1 Install nozzles within the hazard enclosure in compliance with their Approval limitations for the specific manufacturer's clean agent fire extinguishing system.

2.1.3.11 Piping Supports (Hangers)

2.1.3.11.1 Install pipe hangars in accordance with good piping practice. Space hangars in accordance with Table 14. Install a hangar between fittings when the fittings are more than 2 ft (0.6 m) apart. Install a hangar a maximum of 1 ft (0.3 m) from any nozzle located to prevent the nozzle from moving vertically.

Table 14. Recommended Hanger Spacing

Pipe Size in. NPT	*Maximum Spacing between Hangers ft(m)*
¼	4 (1.3)
½	6 (2.0)
¾	8 (2.6)
1	12 (3.9)
1-¼	12 (3.9)
1-½ and larger	15 (4.9)

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2.1.4 Inspection, Testing, Maintenance and Training

2.1.4.1 Inspection and Testing

2.1.4.1.1 Conduct weekly system inspections to see that nozzles are clear and in proper position, that all operating controls are properly set, and that system components have not been damaged.

2.1.4.1.2 At least semiannually, check the agent quantity and pressure of clean agent containers. Refill or replace halocarbon clean agent containers if they show a loss in agent quantity of more than 5% or loss in pressure (adjusted for temperature) of more than 10%. Refill or replace inert gas clean agent containers if they show a loss in pressure (adjusted for temperature) of more than 5%.

2.1.4.1.3 At least annually, thoroughly inspect and test clean agent systems for proper operation exclusive of a discharge test. Inspect and test all actuating and operating devices in accordance with the system manufacturer's recommendations as outlined in the appropriate system design, installation, operation and maintenance manual. Regular service contracts with the system manufacturer's authorized representative are advised.

2.1.4.1.4 At least annually, thoroughly inspect the clean agent system protected enclosure determine if penetrations or other changes have occurred that could adversely affect agent leakage or change the volume of the hazard or both. Correct any conditions discovered during the inspection that could result in inability to maintain the clean agent concentration. If uncertainty still exists with regard to the enclosure integrity, conduct an enclosure integrity test of the enclosure.

Note: It's recommended that a log/record be kept of all changes made to or within the protected enclosure to facilitate the inspection and maintenance of the enclosure integrity.

2.1.4.2 Maintenance

2.1.4.2.1 Maintain clean agent systems in operating condition at all times and restore to service promptly after any impairment or operation. Report any impairments to the local FM Global office so that appropriate precautionary guidance may be obtained. Follow procedures based on the use of the FM Global *Red Tag Permit System.*

2.1.4.2.2 Seal any penetrations made through the clean agent system protected enclosure immediately.

2.1.4.3 Training

2.1.4.3.1 Provide periodic training of plant personnel who may be called upon to inspect, test, maintain or actuate clean agent systems.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 General

Satisfactory performance of a clean agent fire extinguishing system can best be assured by following the loss prevention recommendations within this document.

4.0 REFERENCES

4.1 FM Global

Data Sheet 4-0, *Special Protection Systems.*

Data Sheet 4-11N, *Carbon Dioxide Extinguishing Systems.*

Data Sheet 5-48, *Automatic Fire Detectors.*

F&EC Engineering Form EMV 2332, *Contractor's Application for Acceptance of Gaseous Extinguishing System Installations*, 1/2000.

FM Global *Red Tag Permit System.*

4.2 NFPA Standards

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems, 2000 Edition.*

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4.3 Others

ISO 14520-1:2000, *Gaseous fire-extinguishing systems - Physical properties and system design:*

- *Part 1 General requirements.*
- *Part 2: CF_3I extinguishant.*
- *Part 3: FC-2-1-8 extinguishant.*
- *Part 4: FC-3-1-10 extinguishant.*
- *Part 6: HCFC Blend A extinguishant.*
- *Part 7: HCFC 124 extinguishant.*
- *Part 8: HFC 125 extinguishant.*
- *Part 9: HFC 227ea extinguishant.*
- *Part 10: HFC 23 extinguishant.*
- *Part 11: HFC 236fa extinguishant.*
- *Part 12: IG-01 extinguishant*
- *Part 13: IG-100 extinguishant.*
- *Part 14: IG-55 extinguishant.*
- *Part 15: IG-541 extinguishant.*

ANSI B31.1, *Power Piping Code.*

ASTM A-120, *Specification for Seamless Carbon Steel Pipe for High Temperature Service.*

Fire Safety Technology web site (www.firesafetytech.com)

Fire Suppression Systems Association web site (www.fssa.net)

Infiltec Inc. web site (www.infiltec.com)

Retrotec Inc. web site (www.retrotec.com)

APPENDIX A GLOSSARY OF TERMS

Approved: References to "Approved" in this data sheet means the product and services have satisfied the criteria for FM Approval. Refer to the *Approval Guide* for a complete listing of products and services that are FM Approved.

Clean Agent: Electrically nonconducting, volatile or gaseous fire extinguishant that does not leave a residue upon evaporation.

Engineered System: A system requiring individual calculation and design to determine the flow rates, nozzle pressures, pipe size, area or volume protected by each nozzle, quantity of agent, and the number and type of nozzles and their placement in a specific system.

An engineered system is a designed/flow-calculated system which normally involves the use of a proprietary flow calculation program. The flow calculation program is evaluated/verified through testing as part of the FM Approval process for each fire equipment manufacturer's system. Typically, an engineered system allows for unbalanced piping arrangements, commonly up to 90-10 or 10-90 flow splits.

Fill Density: Mass of agent per unit of container volume, lb/ft^3 (kg/m^3).

Halocarbon Agent: An agent that contains as primary components one or more organic compounds containing one or more of the elements flourine, chlorine, bromine, or iodine.

Inert Gas Agent: An agent that contains as primary components one or more of the gases helium, neon, argon, or nitrogen. Inert gas agents that are blends of gases can also contain carbon dioxide as a secondary component.

Lowest Observed Adverse Effect Level (LOAEL): The lowest agent concentration at which an adverse physiological or toxicological effect has been observed.

No Observed Adverse Effect Level (NOAEL): The highest agent concentration at which no adverse physiological or toxicological effect has been observed.

Pre-engineered System: A system having predetermined flow rates, nozzle pressures and quantities of agent. These systems have the specific pipe size, maximum and minimum pipe lengths, flexible hose specifications, number of fittings, and number and types of nozzles prescribed by a testing laboratory such as FM Approvals.

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A pre-engineered system simply means the system is limited to very specific combinations of pipe sizes and lengths including the total number of tees (flow splits), elbows and nozzles and does not involve flow calculations. Typically, pre-engineered systems are restricted to balanced piping configurations (i.e., 50-50 flow splits).

Safety Factor: A multiplier of the agent flame extinguishing or inerting concentration to determine the agent minimum design concentration.

APPENDIX B DOCUMENT REVISION HISTORY

This document does not have any revision history.

APPENDIX C ADDITIONAL INFORMATION

C.1 General

Clean agents are gaseous fire extinguishing agents which leave no residue. Clean agents are frequently referred to as halon alternatives since they are primarily intended for applications previously covered by the halons which are no longer produced, particularly Halon 1301 and Halon 1211. Clean agent fire extinguishing systems covered by this document use total flooding clean agents primarily intended for applications previously covered by Halon 1301 systems. Clean agents referred to as streaming agents are primarily intended for applications previously covered by Halon 1211, particularly its use within portable extinguishers.

Clean agent fire extinguishing systems are either liquefied halocarbon gas or inert gas types for total flooding application only. See Table 15 for a list of currently recognized clean agents within NFPA 2001 all of which are also addressed within ISO 14520. The clean agents recognized within NFPA 2001 have been evaluated and accepted as total flooding halon alternative agents by the U.S. Environmental Protection Agency under their Significant New Alternatives Policy (SNAP) program.

Table 15. Currently Recognized Clean Agents within NFPA 2001/ISO 14520

Agent/Extinguish	*Chemical Name*	*Trade Name*
Halocarbons		
FC-2-1		
FC-		
Fl		
Inert		
IG-01		
IG-100		
IG-55	gon (50)	
IG-541	(52), Argon (42), Carbon Dioxide (8)	

HCFC Blend A constituents are listed in percent by weight.
Inert gas constituents are listed in percent by volume.

Personnel Safety

Halocarbon clean agents are potentially cardiotoxic while inert gas clean agents can present phsiological effects associated with a hypoxic (i.e., low oxygen) atmosphere. The experimentally determined No Observed

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Adverse Effects Level (NOAEL) and Lowest Observed Adverse Effects Level (LOAEL) values, which are defined in Appendix A, are given in Table 16 for the halocarbon agents. The corresponding NOAEL and LOAEL values for the inert gas agents have been set at 12% oxygen (43% inert gas concentration) and 10% oxygen (52% inert gas concentration) respectively. Inert gas mixture concentrations (e.g., Inergen) can only be determined indirectly by measuring the oxygen concentration within an enclosure.

The clean agent system design extinguishing concentration ideally should be less than the NOAEL for the specific clean agent for occupiable areas. However, system design concentrations in accordance with Section 1-6 of the the 2000 Edition of NFPA 2001, if acceptable to the governing health and safety authority, are acceptable to FM Global.

Table 16. Reported NOAEL/LOAEL Values for Halocarbon Agents

Agent/Extinguishant	*NOAEL ()*	*LOAEL ()*
FC-2-1-8	30	>30
FC-3-1-10	40	>40
FIC-13I1	0.2	0.4
HCFC Blend A	10	>10
HCFC-124	1.0	2.5
HFC-23	50	>50
HFC-125	7.5	10
HFC-227ea	9.0	10.5
HFC-236fa	10	15

Physical properties data for the halocarbon and inert gas type clean agents is provided in Tables 16A, 16B, 17A and 17B.

APPENDIX D BIBLIOGRAPHY

Gaseous Fire Extinguishing Systems using Inert Agents: Guidance for Insurers, LPR 9, Loss Prevention Council, 1998.

Gaseous Fire Extinguishing Systems using Halocarbon Agents: Guidance for Insurers, LPR 10, Loss Prevention Council, 1998.

Gaseous Fire Protection Systems — *Guidance for the Use of Insurers, System Suppliers and their Mutual Clients on the Specification, Installation and On-going Maintenance of Gaseous Fixed Fire Extinguishing Systems*, LPR 16, Loss Prevention Council, 2000.

"Direct Halon Replacement Agents and Systems",Fire Protection Handbook, 18th Edition, National Fire Protection Association, Quincy, MA, 1997.

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Table 16A. Physical Properties of Halocarbon Clean Agents (English Units)

	Units	FC-3-1-8	FC-3-1-10	HCFC Blend A	HCFC-124	HFC-125	HFC-227ea	HFC-23	HFC-236fa	FIC-13I1
Molecular weight	N/A	188	238.0	92.9	136.5	120.0	170.0	70.01	152	195.9
Boiling point at 14.7 psia	°F	–34.4	28	–37.0	10.3	–55.3	1.9	–115.8	29.5	–8.5
Freezing point	°F	–297.4	–199	≤[16]	–326	–153	–204	–247.4	–153.4	–166
Critical temperature	°F	161.4	235	256	252.5	150.8	214	78.6	256.8	252
Critical pressure	psia	388.7	357	964	527	521	422	701	464	586
Critical volume	ft^3/lb	0.026	0.0250	0.0280	0.0289	0.0281	0.0258	0.0305	0.0288*	0.0184
Critical density	lb/ft^3	39.5	39.90	36.00	34.58	35.68	38.76	32.78	34.67*	54.38
Specific heat, liquid at 77°F	Btu/lb-°F	0.25	0.241	0.30	0.276	0.354	0.282	1.087 at 68°F	0.307	0.141
Specific heat, vapor at constant pressure (1 atm) and 77°F	Btu/lb-°F	0.19	0.180	0.16	0.180	0.190	0.185	0.175 at 68°F	0.202	0.86
Heat of vaporization at boiling point	Btu/lb	45.1	41.4	97	70.2	70.8	56.7	103	68.8	48.1
Thermal conductivity of liquid at 77°F	Btu/h-ft-°F	0.008	0.0510	0.052	0.0417	0.0367	0.040	0.0305	0.0431	0.04
Viscosity, liquid at 77°F	lb/ft-hr	0.719	0.785	0.508	0.758	0.546	0.455	0.201	0.74	0.475
Relative dielectric strength at 1 atm at 734 mm Hg, 77°F (N_2 = 1)	N/A	2.2	2.8	1.52	1.55	0.955 at 70°F	2.00	1.04	TBD	1.41
Solubility, by weight, of water in agent at 70°F	ppm	<0.005%	0.001%	0.12%	770 at 77°F	770 at 77°F	0.06%	500 at 50°F	740 at 68°F	0.0062%

*Dupont estimated values.

Table 16A. Physical Properties of Halocarbon Clean Agents (English Units)

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Table 16B. Physical Properties of Halocarbon Clean Agents (Metric Units)

	Units	FC-2-1-8	FC-3-1-10	HCFC Blend A	HCFC-124	HFC-125	HFC-227ea	HFC-23	HFC-236fa	FIC-13I1
Molecular weight	N/A	188	238.03	92.90	136.5	120	170.03	70.01	152	195.91
Boiling point at 760 mm Hg	°C	–37.0	–2.0	–38.5	–12.1	–48.5	–16.4	–82.1	–1.4	–22.5
Freezing point	°C	–183.0	–128.2	<107.2	–198.9	–102.8	–131	–155.2	–105*	–110
Critical temperature	°C	71.9	113.2	124.4	122.6	66	101.7	25.9	124.9	122
Critical pressure	kPa	2680	2325	6647	3620	3595	2912	4836	3200	4041
Critical volume	cc/mole	300.8	371	162	245	210	274	153	274*	225
Critical density	kg/m³	629	629	577	560.72	572	621	525	555.3*	871
Specific heat, liquid at 25°C	kJ/kg °C	1.099	1.047	1.256	1.153	1.481	1.184	4.537 at 20°C	1.283	0.592
Specific heat, vapor at constant pressure (1 atm) and 25°C	kJ/kg °C	0.794	0.804	0.67	0.754	0.794	0.808	0.731 at 20°C	0.844	0.5618
Heat of vaporization at boiling point	kJ/kg	104.8	96.3	225.6	163.1	164.8	132.6	238.8	160.1	112.4
Thermal conductivity of liquid at 25°C	W/m °C	0.0158	0.0537	0.0900	0.0746	0.0634	0.069	0.0527	0.0745	0.07
Viscosity, liquid at 25°C	centipoise	0.297	0.524	0.21	0.305	0.143	0.184	0.083	0.306	0.196
Relative dielectric strength at 1 atm at 734 mm Hg, 25°C (N_2 = 1.0)	N/A	2.2	2.8	1.32	1.55	0.955 at 21°C	2.00	1.04	TBD	1.41
Solubility of water in agent at 21°C	ppm	<0.005% by weight	0.001% by weight	0.12% by weight	700 at 25°C	700 at 25°C	0.06% by weight	500 at 10°C	740 at 20°C	1.0062% by weight

*Dupont estimated values.

Table 16B. Physical Properties of Halocarbon Clean Agents (Metric Units)

Table 17A. Physical Properties of Inert Gas Clean Agents (English Units)

	Units	IG-01	IG-100	IG-541	IG-55
Molecular weight	N/A	39.9	28.0	34.0	33.95
Boiling point at 760 mm Hg	°F	–302.6	–320.4	–320	–310.2
Freezing point	°F	–308.9	–346.0	–109	–327.5
Critical temperature	°F	–188.1	–232.4	N/A	–210.5
Critical pressure	psia	711	492.9	N/A	602
Specific heat, vapor at constant pressure (1 atm) and 77°F	Btu/lb-°F	0.125	0.445	0.195	0.187
Heat of vaporization at boiling point	Btu/lb	70.1	85.6	94.7	77.8
Relative dielectric strength at 1 atm at 734 mm Hg, 77°F (N_2 = 1.0)	N/A	1.01	1.0	1.08	1.01
Solubility of water in agent at 70°F	N/A	0.006%	0.0013%	0.015%	0.006%

Table 17A. Physical Properties of Inert Gas Clean Agents (English Units)

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Table 17B. Physical Properties of Inert Gas Clean Agents (Metric Units)

	Units	IG-01	IG-100	IG-541	IG-55
Molecular weight	N/A	39.9	28.0	34.0	35.95
Boiling point at 760 mm Hg	°C	−189.85	−195.8	−196	−190.1
Freezing point	°C	−189.35	−210.0	−78.5	−199.7
Critical temperature	°C	−122.3	−146.9	N/A	−134.7
Critical pressure	kPa	4,903	5,599	N/A	4,150
Specific heat, vapor at constant pressure (1 atm) and 25°C	kJ/kg °C	0.519	1.04	0.574	0.782
Heat of vaporization at boiling point	kJ/kg	163	199	220	181
Relative dielectric strength at 1 atm at 784 mm Hg, 25°C (N_2 = 1.0)	N/A	1.01	1.0	1.05	1.01
Solubility of waser in agent at 25°C	N/A	0.006%	0.0013%	0.015%	0.006%

Table 17B. Physical Properties of Inert Gas Clean Agents (Metric Units)

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SECTION 15600

HEATING, VENTILATING, AND AIR CONDITIONING

PART 1 – GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing and installing heating, ventilating, and air conditioning systems in accordance with Standard Section 15600 of the Standard Specifications except as modified herein.

1.03 QUALITY ASSURANCE

A. Duct-free split-system shall be rated per ARI Standards 210 "unitary air conditioning equipment"/240 "air source unitary heat pump equipment" and listed in the ARI directory as a matched system.

B. Electric Unit Heaters shall conform to the National Electric Code and Underwriter's Laboratory, Inc., Standard 1025 "Electric Air Heaters".

PART 2 – PRODUCTS

2.04 EQUIPMENT

B. Electric Unit Heaters

1. Unit heater(s) shall be draw-thru design to provide uniform temperature across heater element and forced air cooling of motor with ambient air.
2. Heater elements shall be corrosion protected, steel tubular sheath elements with elements brazed to fins for maximum strength and heat transfer.
3. Furnish with power disconnect. Provide automatic or manual reset thermal cutouts to protect from over-temperature.
4. All motors shall be enclosed, have permanently lubricated bearings and built-in thermal protection. A separate motor supply circuit shall not be required.
5. All units to have a single supply circuit with fuses as required by NEC for element and motor protection.
6. Fans shall be aluminum, directly connected to the fan motor. All units shall have a thermal fan delay switch to prevent blowing of unheated air and to remove residual heat from cabinet by recirculating ambient air until temperature drops to 90° F.
7. An enamel paint finish shall protect all metal cabinet surfaces.
8. Brackets shall be furnished for wall or ceiling mounting where shown on heater schedule.
9. Individually adjustable louvers shall be furnished to direct discharge air as desired. Optional down-flow diffusers shall be provided where shown on schedule (specify radial, cone or four-way adjustable louver).
10. Thermostat shall be provided where shown on schedule (specify built-in or remote room thermostat).
11. Control options provided shall include:
    • 24 Volt control.

• Two step control .

2.36 VENTILATING EQUIPMENT

I. Inline Centrifugal- Same as centrifugal exhaust fans. Provide with filter box as required by the equipment schedule.

2.37 AIR CONDITIONING – DUCTLESS, SPLIT SYSTEM, AIR COOLED

A. The direct-expansion, wall-mounted fan coil unit shall be matched with the condensing unit.. Unit shall be complete with cooling coil, fan, fan motor, piping connectors, electrical controls, control system, and integral temperature sensing. Unit shall be furnished with integral wall-mounting bracket, mounting hardware and condensate pump.

B. The units shall be rated in accordance with ARI Standard 210 and bear the ARI label. System efficiency shall meet or exceed 10.0 SEER. Performance shall be based on 67° FWB, 80° FDB for the fan coil unit and 95°FDB,75°FWB for the Condensing unit.

C. Fan coil unit cabinet – Cabinet discharge and inlet grilles shall be attractively styled, high-impact polystyrene. Cabinet shall be fully insulated for improved thermal and acoustic performance. Discharge louvers shall be manually adjustable.

D. The fan coil unit shall also contain an electric heating coil.

E. Fans – Fan shall be direct-drive blower type with air intake at the upper front face of the unit and discharge at the bottom front.

F. Coil – Coil shall be copper tube with aluminum fins and galvanized steel tube sheets. Fins shall be bonded to the tubes by mechanical expansion. A drip pan under the coil shall have a drain connection for hose attachment to remove condensate. Condensate pan shall have internal trap and auxiliary drip pan under coil header.

G. Motors – Motors shall be open drip-proof, permanently lubricated ball bearing with inherent thermal overload protection. Fan motors shall be 3-speed.

H. Controls Control:

1. This unit shall have a wireless controller to perform input functions necessary to operate the system.
2. The controller shall consist of an Power On-Off switch, Mode Selector, Temperature Setting, Timer Control, Fan Speed Select and Auto Vane selector.
3. The microprocessor located in the indoor unit shall have Self-diagnostic Function, Test Run switching and Check Mode switching.
4. Temperature changes shall be by 2°F increments with a range of 65 - 87°F.

5. The microprocessor located in the indoor unit shall have the capability of sensing return air temperature and indoor coil temperature, receiving and processing commands from the wireless controller, providing emergency operation and controlling the outdoor unit.

I. Filters – Unit shall have filter track with factory-supplied cleanable filters.

J. Electrical Requirements – The equipment schedule identifies the required electrical power characteristics. Power and control connections shall have terminal block connections.

K. System Capacity – Provide systems having capacities as indicated on the Contract Drawings with refrigerant R-22.

L. Air Cooled Condensing Unit – Seamless copper tubes with aluminum fins mechanically bonded and coil circuited for sub-cooling. The unit shall have an accumulator. Condenser fans shall be direct-driven, propeller type Fan motor bearings shall be permanently lubricated. Fans shall be resiliently mounted. Furnish each fan with a safety guard. Include controls for cycling fan(s) for intermediate season operation.

M. The Condensing Unit must have the ability to operate with a maximum height difference of 25 feet and have refrigerant tubing length of 49 feet between indoor and outdoor units without the need for line size changes, traps or additional oil.

2.38 AIR HANDLING UNITS – VENTILATION ONLY

A. Same as paragraph 2.25 "Air Handling Units- Heating and Ventilation" without heating coils and face and bypass dampers. Controls as indicated on the contract drawings.

B. Motors shall be open drip proof "Inverter Duty Motors" in accordance with NEMA MG-1 Part 30 and 31

2.39 CONTROL AND INSTRUMENTATION – ANCILLARY SPACE VENTILAION

A. Sequence of Operation for the ventilation fans in ancillary spaces shall be as described in the following paragraphs.

B. Fan Room

1. Provide a single stage thermostat. Locate thermostat as directed by the Engineer.

2. When the room temperature rises to 85^0F open supply fan damper and exhaust fan damper. Energize supply and exhaust fans.

3. Upon a fall in room temperature to 80^0F, the supply and exhaust fans shall be de-energized, and supply and exhaust fan dampers shall be closed.

4. Provide suitable interlock to shut supply and exhaust fans off when any of the emergency fans B3-EF-1 and B3-EF-2 are energized.

5. Provide a manual time switch to override the thermostatic control of fans and dampers. The time switch shall provide manual control of fans and dampers up to two hours during maintenance. In manual mode, the time switch shall open dampers and run fans up to the selected time period. When the selected time duration is over, the time switch shall return fan controls back to the room thermostat. The time switch shall be capable of being reset up to additional two hours.

6. Provide required interface to the Alarm and Detection System specified in Section 16710, to shut the ventilation system down when smoke is detected within the room.

7. Provide differential pressure switch to measure pressure drop across supply air filter. Provide indication of dirty filter when pressure drop is higher than the set point. Provide the required interface to the Alarm and Detection System specified in Section 16710.

C. Unit Substation Room

1. The sequence of operation of the supply and exhaust fans in the Unit Substation Room shall be similar to that specified for the Fan Room ventilation fans in Paragraph 2.39.B above.

2, Provide a manual time switch to override the thermostatic control of fans and dampers. The time switch shall have the same features and functions as specified in Paragraph 2.39.B.

3, Provide required interface to Alarm and Detection System specified in Section 16710, to shut the ventilation system down when smoke is detected within the room.

4. Provide differential pressure switch to measure pressure drop across supply air filter. Provide indication of dirty filter when pressure drop is higher than the set point. Provide the required interface to the Alarm and Detection System specified in Section 16710.

D. MCC Rooms

1. Provide a single stage thermostat. Install thermostat as indicated on the Drawings and as directed by the Engineer in the field.

2. When the room temperature rises to 80^0F open supply fan damper and exhaust fan damper. Energize supply and exhaust fans.

3. Upon a fall in room temperature to 75^0F, the supply and exhaust fans shall be de-energized, and supply and exhaust fan dampers shall be closed.

4, Provide a manual time switch to override the thermostatic control of fans and dampers. The time switch shall have the same features and functions as specified in Paragraph 2.39.B.

5, Provide required interface to Alarm and Detection System specified in Section 16710, to shut the ventilation system down when smoke is detected within the room.

6. Provide differential pressure switch to measure pressure drop across supply air filter. Provide indication of dirty filter when pressure drop is higher than the set point. Provide the required interface to the Alarm and Detection System specified in Section 16710.

4.02 PAYMENT. Heating, ventilating, and air conditioning work as specified in this section will be paid for at the Contract lump sum price for heating, ventilating, and air conditioning work.

ITEM NUMBER	PAYMENT ITEM	UNIT
1559.020	HEATING, VENTILATING AND AIR CONDITIONING SYSTEM	LUMP SUM

END OF SECTION

SECTION 15800

AIR DISTRIBUTION

PART 1 – GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing, installing, balancing, and testing ductwork and accessories for the air distribution systems in accordance with Standard Section 15800 of the Standard Specifications except as herein modified.

1.02 ABBREVIATIONS

A. ARI- American Refrigeration Institute

D. ASTM- American Society of Testing and Materials

1.03 QUALITY CONTROL

A. Performance Requirements. Provide air supply devices complying with the following:

1. Testing: Test performance according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."

2. ARI 890-2001: Rating of Air Diffusers and Air Diffuser Assemblies

3. ARI 885-98: Procedure for Estimating Occupied Space Sound Levels in the Application of Air Terminals and Air Outlets

2.02 MATERIALS

A. Galvanized Steel

1. Steel Sheets No. 14 Gauge or lighter: ASTM A653/A653M-03 Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process and ASTM A924/A924M-99 Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process

2.03 FABRICATION

A. Ductwork

1. Duct construction details and metal gauges shall conform to SMACNA HVAC Duct Construction Standards, referred to herein as the Duct Manual, except where necessary to increase gauges and supports for structural strength or other particular needs. Provide electrical isolation between dissimilar metals.

2.04 MANUFACTURED PRODUCTS

I. Electric Duct Heaters

7. Conform to UL 1025 "Electric Air Heaters" and the NEC

3.01 INSTALLATION

I. Seismic Supports and Restraints: Support duct systems in accordance with the SMANCA Seismic Restraint Manual: Guidelines for Mechanical Systems

4.02 PAYMENT. Air distribution systems will be paid for at the Contract lump sum price for air distribution systems.

ITEM NUMBER	PAYMENT ITEM	UNIT
1580.010	AIR DISTRIBUTION	LUMP SUM

END OF SECTION

SECTION 15801

EMERGENCY VENTILATION SYSTEM ACCESSORIES

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the furnishing and installing of Emergency Ventilation System Accessories.

B. The work specified in this Section consists of furnishing and installing all equipment, as shown on the Drawings, including the vibration isolators, sound attenuators, flexible connections, ductwork, and all structural support elements and hardware for the installation of equipment.

C. Related Work Specified Elsewhere:

1. Section 05500 Miscellaneous Metal
2. Section 09900 Painting
3. Section 15050 Basic Materials and Methods for Mechanical Work
4. Section 15805 Tunnel Ventilation Fan-Motor Units
5. Section 15859 Emergency Ventilation Dampers

1.03 QUALITY CONTROL

A. Materials and workmanship shall be in accordance with the latest edition of the following standards and codes to the extent specified herein. The publications listed below form a part of these specifications to the extent referenced. The publications are referred to in the text by basic designation only.

1. American National Standards Institute (ANSI)
   a. B18.21.1, Lock Washers.
   b. C1, Specifications of General Requirements of a Quality Program.
2. American Society for Testing and Materials (ASTM)
   a. A36, Structural steel.
   b. A123, Zinc (Hot Galvanized) Coatings on Products Fabricated from Rolled, Pressed and Forged Steel Shapes, Plates, Bars, and Strip.
   c. A167, Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip.

d. A193, Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service.

e. A194, Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service.

f. A239, Locating the Thinnest Spot in Zinc (Galvanized) Coating on Iron or Steel Articles by the Preece Test (Copper Sulfate Dip).

g. A666, Austenitic Stainless Steel Sheet, Strip, Plate and Flat Bar for Structural Applications.

h. E84, Surface Burning Characteristics of Building Materials.

i. E477, Measuring Acoustical and Airflow Performance of Duct Liner Materials and Prefabricated Silencers.

3. American Welding Society (AWS)

a. D1.1, Structural Welding Code - Steel.

b. D1.3, Structural Welding Code - Sheet Steel.

4. National Fire Protection Association (NFPA)

a. 90A, Installation of Air Conditioning and Ventilating Systems.

5. Sheet Metal and Air Conditioning Contractor's National Association Inc. (SMACNA)

a. Rectangular Industrial Duct Construction Standards.

6. Steel Structures Painting Council (SSPC)

a. PA-1, No. 1 Shop, Field and Maintenance Painting.

b. PA-2, Method for Measurement of Dry Paint Thickness with Magnetic Gauges.

c. SP-1, Solvent Cleaning.

d. SP-2, Hand Tool Cleaning.

e. SP-3, Power Tool Cleaning.

f. SP-6, Commercial Blast Cleaning.

g. SP-10, Near White Blast Cleaning.

B. Welding: All Components in this Contract requiring welding shall be welded as follows:

1. Code Requirement: Welding shall conform to the requirements of AWS D1.1 and AWS D1.3.

2. Welder Qualification: Welders welding on the work of this project shall be qualified in accordance with the requirements of AWS D1.1, Section 5, Qualification.

3. Process: The welding process employed on the Work of this project shall be the shielded metal arc process, in accordance with the requirements of AWS D1.1, Section 5, Qualification.

1.04 SUBMITTALS

A. See Section 16070, SUBMITTALS, Page 16070-2, Paragraph 1.03 for requirements for Coordination Drawings for Mechanical and Electrical work.

B. Within 15 days after Notice to Proceed Contractor shall submit names and qualifications of manufacturers of sound attenuators. Such qualification statements shall include, but need not be limited to the following data:

1. Certified performance data of equipment proposed to be furnished under this Contract.

2. Manufacturer's quality assurance programs in accordance with ANSI C1.

3. Complete list of projects on which similar equipment specified herein for rail projects in the U.S. have been installed or furnished. List shall include:

a. Name of authority or user (Include Authority installations, if any).

b. Contract number(s).

c. Original installation date(s).

d. Current condition of equipment.

e. A list of all known failures including apparent cause(s), corrective work affected, and description of equipment service and operating conditions.

4. List of components to be purchased from other manufacturers. Give name of manufacturer, type and characteristic of each item, and include for each the data requested under Paragraphs 1 through 3 above.

C. Within 45 days after Notice to Proceed the Contractor shall submit the following:

1. Certified shop drawings, including Bill of Materials, for fan ductwork, vibration isolators, flexible connections, screens and sound attenuators; installation drawings, installation instructions; dimensioned drawings for installation of structural steel members (columns, mullions, lintels, and other structural support members) to be furnished by manufacturer; weight of components and any additional components and any additional data required for proper installation.
2. Certificate of Compliance signifying that equipment to be furnished under this Contract meets the requirements specified herein.

3. List of technical support items specified and list of any additional support items required.

D. Within 14 days after successful completion of all factory tests specified herein and of any additional tests conducted at the Contractor's own option, the Contractor shall submit the following:

1. Certified results for all tests conducted. All data shall be bound in one report. The test report shall be indexed and cross referenced in an easily understood manner.

2. All records and results of non-destructive examinations made at completion of each examination.

3. Field sound test procedures.

1.05 JOB CONDITIONS

A. Surfaces and structures to which the products will be affixed, placed, and installed shall be inspected by the Contractor in the presence of the equipment manufacturer and Authority before the work begins. Surfaces which will be concealed by products shall be finished before products are installed.

PART 2 - PRODUCTS

2.01 EMERGENCY FAN DUCTWORK

A. Ductwork

1. General

a. Ductwork and all parts thereof shall be capable of withstanding the thermal expansion and operational stresses for not less than 1 hour in an ambient temperature of not less than 482 degrees Fahrenheit (250 degrees Celsius).

b. Ductwork shall be fabricated of galvanized hot-rolled steel not less than No. 10 United States Standard Gauge and shall have companion flanges at both ends.

c. Ductwork shall be designed in accordance with SMACNA 1995 to withstand + / - 14 inches water gauge differential pressure resulting from possible operation of the emergency fan against a closed damper.

d. Ductwork shall be fabricated in multiple sections. Each multiple section shall be fabricated and assembled flanged, gasketed and bolted together to form an airtight perimeter. The ductwork side sheets shall be connected together by continuous welding.

e. Each multiple section shall be match-marked with stencils in a conspicuous location for identification at the site. The sections shall be of such size which can be brought into the fan rooms through the access provided and to facilitate handling, erection, and disassembly.

f. Ductwork shall be stiffened with reinforcing angles properly located in sufficient quantity on its exterior to limit ductwork panel vibration to not more than 50 percent of ductwork panel metal thickness during fan-motor unit operation. Terminating ends of reinforcing angles shall be rounded or beveled.

g. Steel for ductwork reinforcement and section connection flanges shall be structural angle sections conforming to the requirements of Specification for Structural Steel, ASTM A36. Angles shall not be less than 3 inches by 3 inches by 3/8-inch thick, except for vertical ductwork sections which are supported from the roof of the N-2 Vent Building and extend through the roof slab opening, which shall not be less than 2 inches by 2 inches by 1/4-inch-thick. Companion flanges and reinforcing angles shall be continuously welded to the perimeter of each multiple duct section.

h. Companion flanges shall have punched or drilled holes equally spaced not more than 6 inches on centers to permit bolting to adjacent components.

i. Access doors shall be the same material as ductwork and shall be provided where indicated. Each access door shall have a clear opening size not less than 30 inches high by 24 inches wide. Access doors shall be provided with not less than 1/4-inch-thick silicone gaskets to insure air-tight construction. Access doors shall be provided with wedge type latches, and welded full height continuous stainless steel hinge. Hand hold bar shall be provided above top of access door. Portable metal ladders shall be provided, one at each fan location.

j. Ductwork supports shall be of the same material as ductwork and shall not be less than 3/8-inch thick. The supports shall be welded to the ductwork and cross-braced to provide rigidity.

k. Contractor shall provide a 1/4-inch-thick silicone gasket between all adjacent companion flanges; width of gaskets shall be same as flange width. Gaskets, shall be capable of withstanding an ambient temperature of not less than 482 degrees Fahrenheit (250 degrees Celsius) for not less than 1 hour without degradation of sealing ability and without emitting toxic or noxious fumes.

B. Flexible Connections

1. Flexible connections shall be as indicated on the Contract Drawings and consist of fabric connector material and fabric securing bars. Flexible connections shall be fabricated from material capable of operating for not less than 1 hour without failure in an ambient temperature of not less than 482 degrees Fahrenheit (250 degrees Celsius).

2. Flexible connections shall be designed to allow sufficient radial, axial, rotational and lateral movement of fan-motor unit assembly resulting from expansion, contraction and dynamics of air moving unit operations, without unnecessary slack in fabric connector material.

3. Flexible connections and all components thereof shall be designed to be airtight and provided in accordance with the code requirements of the applicable NFPA 90A.

4. Flexible material shall have a nominal thickness of not less than 1/8-inch; it shall be flame resistant, abrasion resistant, and able to withstand, without deleterious effect, saturation with

grease and oil. The corners on rectangular flexible connections shall be completely molded and free of splices. The flexible portion shall be a minimum of 12 inches wide.

5. Companion flange angles shall have punched or drilled holes to receive 1/2-inch diameter bolts. The hole spacing shall exceed 4 inches on center. The companion flanges shall be an integral part of the flexible connection.

6. The fabric securing bar shall be a minimum of 3/8-inch-thick by 2 inches wide and fabricated from stainless steel chambered or rounded edge bar stock conforming to ASTM A666, Type 304 Grade A.

7. Flexible connections shall not be painted or used to correct misalignment.

C. Screens

1. Unless otherwise specified herein or indicated on the Contract Drawings, guard screens shall be 2-inch diamond woven mesh fabricated of No. 8 U.S.S. gauge steel wire stubs iron gauge. The screen shall be reinforced across the shorter dimension with 1 1/2-inch by 1 1/2-inch by 10 GA galvanized steel angles at midpoint. Guard screen shall be provided with rigid flanges not less than 1-inch-wide, designed for bolting to mating companion flanges. The guard screen, including the flanges, shall be hot-dipped galvanized after fabrication. The galvanizing shall conform to ASTM A123 and shall withstand an eight-dip Preece test in accordance with ASTM A239.

2. Screen frames shall be bolted to companion flanges with bolts spaced not more than 12 inches on center.

D. Vibration Isolators

1. Pad type equipment shall be furnished with ribbed neoprene or Fabreeka pads of not less than 1/2-inch thickness and of adequate deflection to minimize transmission of high frequency vibration and vibrating frequencies associated with fan running speeds and first three multiples (harmonics) thereof. Provide neoprene sleeves and neoprene washers to adequately isolate anchor bolts. Emergency fans shall be mounted and leveled using "Stainless Steel Shim Packs" with vibration isolation pads as shown on the Drawings.

2. Spring Type:

a. Spring Isolators: Provide spring isolators which are adjustable, free-standing, laterally stable without housings, and with neoprene acoustic friction pads at least 1/4-inch-thick between base plates and supports. The horizontal stiffness of isolators shall be at least 0.8 of the vertical (axial) stiffness.

b. Springs: Springs shall be securely fastened to base and compression plates and designed so spring ends remain parallel during and after deflection to operating height. Outside coil diameters shall be at least 0.8 of the operating height. At operating height, springs shall have additional travel to complete (solid) compression equal to at least 50 percent of the operating deflection.

c. Mounting and Adjustment: Provide base and compression plates with mounting holes or threaded fittings. Adjustment leveling bolts shall be rigidly bolted to machinery or base.

E. Sound Attenuators:

1. General: The sound attenuator units shall be of the dimensions (width/height/length) shown on the Contract Drawings. Each horizontal sound-attenuating unit shall be comprised of square or rectangular modules. Each module shall be factory fabricated into an outer casing. All of the modules in any given unit shall be of the same length. Outer casing for the horizontal units shall be sufficiently modularized to allow for ease of disassembly, installation and re-assembly. Each vertical sound attenuator shall be of the prefabricated acoustic splitter silencer type and shall be similar to "Quiet-Flow" components manufactured by Industrial Acoustics Company.

a. Maximum face velocity is defined as average cross-sectional velocity, perpendicular to the direction of flow, at flow rate (cubic feet per minute) through the sound attenuating unit.

b. Maximum static pressure loss is defined as the pressure loss across the sound attenuating unit at the maximum face velocity, based on aerodynamic performance tests in accordance with applicable ASTM, E477 test codes.

c. The pressure drop through each sound attenuator under specified airflow conditions shall not exceed the maximum acceptable values shown in the sound attenuator schedule.

d. Sound attenuator shall provide full octave band dynamic insertion loss (DIL) not less than the values specified in the attenuator performance schedule. The DIL in the 1/3 octave bands containing the fan blade pass frequency and first harmonic shall not be less than the indicated full octave band values. The selection of sound attenuators shall be coordinated with the associated fan design specified in Section 15805 Tunnel Ventilation Fan-Motor Units.

e. The self-generated noise of any sound-attenuating modules or silencer assembly (corrected to include face area adjustment factors) shall not exceed the sound power level of the fan motor unit minus the dynamic insertion loss of the element in any octave band.

2. Materials

a. General

(1) The materials and methods used to fabricate the sound attenuating modules or acoustic splitters and to assemble them into units shall be selected and designed to permit operation for 1 hour in an ambient temperature of 482 degrees Fahrenheit (250 degrees Celsius).

(2) Outer casings of both the modules and the units shall be fabricated of not less than No. 18 United States Standard Gauge galvanized steel in accordance with SMACNA Duct Manual and Sheet Metal Construction for Ventilation and Air Conditioning Systems Section II, High Velocity Systems. Outer casings shall be sufficiently

modularized to allow for ease of disassembly, installation, and re-assembly. Outer casing shall be sufficiently braced with reinforcing angles to minimize vibration during operation. Sound-attenuating units shall be furnished with flanges at both ends where required, to permit the units to be rigidly bolted to adjacent components. Flanges shall be fabricated of galvanized steel structural angles and shall be bolted to the outer periphery of the casings unless otherwise indicated. Angles shall be protected by an additional coating of zinc-rich paint after installation. Gaskets or sealant, if required, shall be capable of withstanding an ambient temperature of not less than 482 degrees Fahrenheit (250 degrees Celsius) for not less than 1 hour without degradation of sealing ability.

(3) Filler material shall be inorganic mineral or glass fiber of a density sufficient to obtain the required acoustic performance, and shall be packed under not less than 5 percent compression, to eliminate voids due to vibration and settling. The material shall be inert, vermin-proof, and resistant to high humidity conditions. The combustion rating of the filler material, when tested in accordance with ASTM E84, NFPA 255 and UL 723, shall be not greater than the following:

Flame Spread Classification - 20

Smoke-Developed Rating - 20

The acoustical fill shall comply with UL 181 for impact and erosion characteristics.

b. Horizontal Sound Attenuators

(1) Interior partitions of the sound attenuator modules shall be formed of not less than No. 22 United States Standard Gauge galvanized steel sheet perforated to provide the required acoustic transparency. Interior partitions shall be located 2 inches from edge of sound attenuator outer casing.

c. Vertical Sound Attenuators

(1) Acoustic splitters shall be of a quantity, length, thickness and spacing to achieve the minimum acoustic performance specified with the maximum self-noise and maximum allowable pressure drop specified.

(2) Perforated splitter facings shall be a minimum of No. 18 United States Standard Gauge Type #G-165 galvanized perforated steel. The perforated pattern shall have 3/32-inch diameter holes spaced on 3/16-inch staggered centers.

(3) Internal splitter reinforcement shall be a minimum of No. 18 United States Standard Gauge Type #G-165 galvanized steel and spaced so this the span does not exceed 2-feet, 0-inches.

3. Construction

a. General

(1) Sound-attenuators shall be designed and structurally reinforced to withstand + / - 14 inches water gauge differential pressure resulting from possible operation of the emergency fan against a closed damper. Under these pressure conditions, air leakage from or into the sound attenuator shall not exceed 10 cubic feet minute per square foot of face area.

(2) Sound-attenuating units shall be furnished complete with all legs, and/or other structural support elements required for installation. Structural support elements shall be designed to be bolted to the outer casing of sound-attenuating units, except where noted in the Contract Drawings. All parts of the structural bracing and support elements shall have either a hot-dipped or an electro-deposited zinc coating. The weight of the zinc coating shall not be less than 2.5 ounces per square foot. The zinc coating shall be applied after the structural support elements are fabricated. The use of zinc-pigmented paint in lieu of galvanizing will not be allowed except for protection of welded areas. The galvanizing shall conform to ASTM A123; and shall withstand an 8-dip Preece Test in accordance with ASTM A239.

(3) Sound-attenuators shall be designed to be readily disassembled and reassembled in the field, in the event that such disassembly/re-assembly is necessitated by the physical constraints of the installation. Sound-attenuating units shall be designed to be capable of all operating and performance requirements specified herein, when the elements are disassembled and reassembled in accordance with the explicit, written instruction of the manufacturer of the elements.

(4) Companion flanges shall have punched or drilled holes equally spaced not more than 12 inches on center unless otherwise indicated.

b. Horizontal Sound Attenuators

(1) Continuous metallic nosing fabricated of not less than No. 22 U.S.S. gauge galvanized steel shall be provided to prevent air and sound leakage through the abutting surfaces when the sections are installed in the field to make up one complete sound attenuator unit.

(2) Steel for sound attenuator reinforcement requirement and section connection flanges shall be galvanized structural angle sections conforming to the requirements of ASTM A36. Angles shall be not less than 3 inches by 3 inches by 3/8-inch-thick. Sound attenuator panel bracing shall be of sufficient quantity and properly located to limit panel vibrations to not more than 50 percent of panel metal thickness.

c. Vertical Sound Attenuators

(1) The silencer bank assembly shall be provided in components engineered to fit the space available. Complete assembly instructions shall be provided by the manufacturer. The finished assembly shall be self-supporting with individual splitters removable for access when required.

(2) Individual splitters shall be provided with sufficient lifting lugs to facilitate on site installation and removal of the splitters.

(3) Perimeter and internal reinforcement and panel sheets shall be welded and riveted to form a rugged metal-sheathed acoustic panel. Spot welds shall not exceed 3 inches on center.

(4) Prior to attaching the face sheets, the splitters shall be filled with sound retardant and absorbing acoustic fill material. The fill shall be slightly larger and thicker than the inside dimensions of the acoustic baffle.

(5) The face sheet shall be welded and riveted to the assembly so as to compress and hold the fill materials in place under conditions of vibration such as encountered in shipment, installation, and operation.

(6) Attachment channels, aprons, splitter joiners, and angles shall be provided by the manufacturer and shall be galvanized steel. Where required, splitter panel joiners shall be roll formed H-sections. Where roll formed joiners cannot be used, No. 16 galvanized attachment sections shall be provided. All joiners and connectors requiring felted or gasketed surfaces shall have the felt/gasket provided by the manufacturer and applied in the field during installation.

(7) Steel for sound attenuator reinforcement requirement and section connection flanges shall be galvanized structural angle sections conforming to the requirements of ASTM A36. Angles shall be not less than 2 inches by 2 inches by 1/4-inch-thick. Sound attenuator panel bracing shall be of sufficient quantity and properly located to limit panel vibrations to not more than 50 percent of panel metal thickness.

4. Nameplates: Each sound attenuator unit shall be provided with a nameplate fabricated of Type 316 stainless steel not less than 10 gauge thick, permanently stamped with the name and address of the manufacturer, Contractor's identification number, model type, shop order number and serial number and Authority designated attenuator number. The nameplate shall be securely attached to the exterior of the attenuator unit in a conspicuous location.

   a. The forward (exhaust) direction of airflow shall be permanently marked on each sound attenuating module or unit.

5. Factory Testing

   a. The Engineer may, at his option, witness any or all of the tests specified herein. The Contractor shall notify the Authority, in writing, not less than 3 weeks in advance as to the location and dates of all factory tests.

   b. Prior to fabrication of sound attenuators to be furnished under this Contract, one sound attenuating duct unit of each type consisting of at least four modules (2 modules high x 2 modules wide), or a test unit having minimum cross-sectional area of 24 inches by 24 inches, shall be factory-tested. The test unit shall represent the full aerodynamic and acoustical design features of the assembled sound attenuator unit. The tests shall be conducted at the operating pressure specified and certified test reports of performance shall be furnished to the Engineer for approval. Factory testing of sound attenuators shall be in accordance with the requirements of ASTM E477. Test procedures shall be submitted to the Authority for approval prior to the factory tests.

c. The acoustic performance ratings are indicated in the Sound Attenuator Equipment Schedule. The acoustic performance of the test module shall equal or exceed the indicated ratings.

d. The acoustic performance of the test unit shall be determined using a duct-to-reverberant-room test facility which provides for airflow in both directions through the module during the rating procedure. The test facility and rating procedure shall be such, to the satisfaction of the Engineer, that all effects due to end reflection, directivity, flanking transmission, standing waves, and test-chamber sound absorption are eliminated. Acoustic performance ratings shall include dynamic insertion loss for both forward flow through the test unit (airflow and sound transmission traveling in the same direction), and for reverse flow through the test unit (airflow and sound transmission traveling in opposite directions). The ratings shall be determined with air flowing uniformly over the entering face of the test unit at 2,000 feet per minute. Acoustic performance data shall be presented in tabular form showing decibels at eight octave-band center frequencies from 63-Hertz to 8,000-Hertz, and at the 1/3 octave band center frequencies containing the fan blade pass frequency and first harmonic.

e. Acoustical-performance of sound attenuating duct elements shall be determined in an acoustical laboratory which is accredited by the National Voluntary Laboratory Accreditation Program (NVLAP) for ASTM E477 testing. Prior to proceeding with the performance certification testing, the Contractor shall submit for the Engineer's approval schematic drawings of the test facility, identifying all test instruments, and test procedures. A copy of the NVLAP accreditation certificate for the test facility shall be included

f. Aerodynamic performance data shall be determined for the identical test units for which acoustic performance is specified, and under the same conditions of airflow. Airflow measurements shall be made in accordance with the applicable portions of ASTM Standard E477. Static pressure loss through the test unit at the indicated airflow rate shall not exceed the values indicated in the Sound Attenuator equipment schedule.

6. Installation Hardware

a. Fasteners

(1) In accessible areas, fasteners shall be hexagonal head bolts with hexagonal head nuts, washers and heavy duty lock washers.

(2) In inaccessible areas, fasteners shall be hexagonal head tap bolts with suitable flat washers and heavy duty lock washers.

(3) Bolts shall not be less than 1/2-inch in diameter unless otherwise indicated.

(4) Bolts and tap bolts shall be stainless steel and shall conform to the requirements of ASTM A193, Grade B8M or B8MA, equivalent to AISI Type 304, with suitable lock washers.

(5) Nuts shall be stainless steel and shall conform to the requirements of ASTM A194, Grade 2H, equivalent to AISI Type 304.

(6) Galvanized steel bolts, nuts and lock washers shall be used on galvanized components. The bolts shall conform to ASTM A325, Type 1 galvanized; the nuts shall conform to ASTM A563, Grade DH galvanized and the lock washers shall be galvanized steel conforming to ANSI B18.21.1.

b. Expansion Bolts

(1) Expansion bolts for bolting sound attenuator units to concrete floor shall be double element type of not less than 5/8-inch in diameter, with suitable flat and heavy-duty lock washers.

(2) Anchors in lieu of expansion bolts shall be submitted for approval. Expansion bolts or anchors shall be of the same corrosion-resistant material as specified in Paragraph 6.a.3 above.

F. Shop Finishes

1. After fabrication and prior to assembly, all inside and outside surfaces of all ductwork shall be prepared in conformity to the requirements of SP-10 Near White Blast Cleaning and shall be given a rust-inhibiting coating, which may consist of an approved plastic coating, or bonderizing, or phosphatizing, followed by the application of a suitable rust-inhibiting primer and finish paint that is resistant to abrasion and to exposure to elevated temperatures. Surface finish shall be capable of withstanding:

a. An ambient temperature of not less than 482 degrees Fahrenheit (250 degrees Celsius) for not less than 1 hour without degradation of its protective quality, and without emitting toxic or noxious fumes.

b. Two hundred hours in salt spray fog test, in accordance with Method 6061 of Federal Test Method Standard No. 141. Immediately upon removal of the panel from the test, the film shall not show any visible blistering or rust spots, and there shall not be over 1/8-inch of rust creepage on either side of the scratch mark.

c. Provide colors conforming to Method A, Color Selection Made After Award of Contract.

d. Surface finishes damaged during transport or assembly shall be restored to their original condition and color by the installing contractor.

PART 3 - EXECUTION

3.01 INSTALLATION

A. General

1. Products shall be installed, aligned, connected, and tested in accordance with approved working and shop drawings, and in accordance with the respective equipment manufacturer's printed installation instructions and under supervision of equipment manufacturer's field service engineer.

a. Contractor shall furnish hardware to companion flange attachment for companion flanges. Hardware shall be stainless steel bolts, nuts, and flat washers in accordance with SECTION 05500, MISCELLANEOUS METALS, and stainless steel lock washers in accordance with ASTM A313.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. No separate measurement will be made for work required under this section but all costs shall be included in the pay item TUNNEL VENTILATION SYSTEMS which will be paid for on under a lump sum basis, complete in place including all terminations, relocation of existing feeders, testing, connections, staging, demolition and incidentals as shown on the Drawings and specified herein.

4.02 PAY ITEMS

ITEM NO.	DESCRIPTION	UNIT
1586.040	TUNNEL VENTILATION SYSTEMS	LS

END OF SECTION

SECTION 15805

TUNNEL VENTILATION FAN-MOTOR UNITS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the requirements for furnishing tunnel ventilation fan-motor units and appurtenances as shown on the Contract Drawings and specified herein.

B. Related Work Specified Elsewhere:

1.	Section 05500	Miscellaneous Metal
2.	Section 09900	Painting
3.	Section 15050	Basic Materials and Methods for Mechanical Work
4.	Section 15801	Emergency Ventilation System Accessories
5.	Division 16	Electrical
6.	Section 16314	Communication Programmable Logic Controller

1.02 QUALITY CONTROL

A. Source Quality Control

1. Fans shall be the product of a single manufacturer whose name shall appear on the theatrical fan-motor unit performance curves and other data submitted.

2. All motors shall be the product of a single manufacturer whose name shall appear on the theatrical motor performance curves and other data submitted.

B. Manufacturer's Qualifications: The fan manufacturer shall submit documents to show continuous and current experience in the design, assembly, and testing of axial flow tunnel ventilation fans and experience in the design and fabrication of units capable of operating in an airstream at a temperature of not less than 482 degrees Fahrenheit (250 degrees Celsius) for not less than 1 hour.

C. Materials and workmanship shall be in accordance with the latest edition of the following standards and codes to the extent specified herein. The publications listed below form a part of these specifications to the extent referenced. The publications are referred to in the text by basic designation only.

1. Air Moving and Control Association (AMCA):

a. 210, Laboratory Methods of Testing Fans for Rating.

2. American National Standards Institute (ANSI):

   a. C1, Specifications of General Requirements of a Quality Program.

   b. S12.36, Survey Methods for Determination of Sound Power Levels of Noise Sources.

3. American Society for Testing and Materials (ASTM):

   a. A36, Structural Steel.

   b. A123, Zinc (Hot Galvanized) Coatings on Products Fabricated from Rolled, Pressed and Forged Steel Shapes, Plates, Bars, and Strip.

   c. A193, Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service.

   d. A194, Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service.

   e. A239, Locating the Thinnest Spot in Zinc (Galvanized) Coating on Iron or Steel Articles by the Preece Test (Copper Sulfate Dip).

   f. A325, Structural Bolts, Steel, Heat Treated 120/105 KSI Minimum Tensile Strength.

   g. A388, Standard Recommended Practice for Ultrasonic Examination of Heavy Steel Forgings.

   h. A563, Carbon and Alloy Steel Nuts.

   i. A653, Steel Sheet, Zinc Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.

   j. E94, Radiographic Testing.

   k. E138, Wet Magnetic Particle Inspection.

   l. E155, Reference Radiographs for Inspection of Aluminum and Magnesium Castings.

4. American Welding Society (AWS):

   a. D1.1, Structural Welding Code - Steel.

   b. D1.3, Structural Welding Code - Sheet Steel.

5. Anti-Friction Bearings Manufacturers Association (AFBMA).

   a. 9, Load Ratings and Fatigue Life for Ball Bearings.

   b. 11, Load Ratings and Fatigue Life for Roller Bearings.

6. Institute of Electrical and Electronic Engineers (IEEE):

a. 112, Test Procedure for Polyphase Induction Motors and Generators.

b. 519, Recommended Practices and Requirements for Harmonic Control in Electric Power Systems.

7. Military Specifications (Mil. Spec.):

a. MIL-P-24441/A, General Specification for (Ships), Paint, Epoxy Polyamide.

b. MIL-P-24441/1A, Paint, Epoxy Polyamide, Green Primer, Formula 150, Type 1.

c. MIL-P-24441/2A, Paint, Epoxy Polyamide, Exterior Top Coat, Haze Gray, Formula 151, Type 1.

8. National Electrical Manufacturer's Association (NEMA):

a. ICS-1, General Standards for Industrial Control and Systems.

b. ICS-1.1, Safety Guidelines for the Application, Installation and Maintenance of Solid-State Control.

c. ICS-2, Industrial Control Devices, Controllers and Assemblies.

d. ICS-3, Industrial Systems.

e. MG-1, Motors and Generators.

f. MG-1-12.54, Efficiency.

9. National Fire Protection Association (NFPA)

a. 70, National Electrical Code.

10. Steel Structures Painting Council (SSPC):

a. PA-1, No. 1 Shop, Field and Maintenance Painting.

b. PA-2, Method for Measurement of Dry Paint Thickness with Magnetic Gauges.

c. SP-1, Solvent Cleaning.

d. SP-2, Hand Tool Cleaning.

e. SP-3, Power Tool Cleaning.

f. SP-6, Commercial Blast Cleaning.

g. SP-10, Near White Blast Cleaning.

11. Underwriter's Laboratories, Inc. (UL):

    a. 508, Industrial Control Equipment.

D. Welding: All components in this Contract requiring welding shall be welded as follows:

1. Code Requirement: Welding shall conform to the requirements of AWS D1.1 and AWS D1.3.

2. Welder Qualification: Welders welding on the work of this project shall be qualified in accordance with the requirements of AWS D1.1, Section 5, Qualification.

3. Process: The welding process employed on the Work of this project shall be the shielded metal arc process, in accordance with AWS D1.1.

1.03 SUBMITTALS

A. Within 15 days after Notice to Proceed the Contractor shall submit evidence of his qualifications, including, but not limited to the following data:

1. Theoretical fan-motor composite performance curves for equipment proposed to be furnished under this Contract.

    a. Fan-motor unit performance curves from shut-off to free delivery shall have the following data plotted as ordinates versus airflow rate, in cubic feet per minute, as abscissa:

        (1) Total pressure, inches of water.

        (2) Static pressure, inches of water.

        (3) Velocity pressure, inches of water

        (4) Total efficiency, percent.

        (5) Static efficiency, percent.

        (6) Horsepower input to fan impeller.

        (7) Kilowatt input to the motor.

    b. Separate curves shall be furnished for forward and reverse direction. Each curve shall be identified.

    c. The system resistance curve shall be plotted on each curve for one, two, three, and four fan operation. The point of operation shall be indicated.

    d. In addition, furnish the following data:

        (1) Theoretical performance curves for each rotational direction shall be plotted for fan motor units for the installed motor horsepower for the following blade pitch angles:

(a) Maximum blade pitch angle for installed motor horsepower.

(b) Minimum blade pitch angle.

(c) Design blade pitch angle.

(d) A minimum of two intermediate pitch angles between maximum and minimum blade pitch angle other than design pitch angle.

(2) These performance curves shall be plotted with abscissa as cubic feet per minute and ordinates as:

(a) Total pressure, in inches of water.

(b) Horsepower input to fan impeller.

(c) Annulus velocity pressure in inches of water.

(d) System resistance curve showing operation point.

(3) Acceleration time for each rotational direction from standstill to operating revolutions per minute. Plot operating revolutions per minute as abscissa and acceleration time as ordinate.

(4) The fan load torque curve at operating speed. Plot percent revolutions per minute as abscissa and percent full-load torque as ordinate.

e. All performance curves shall be plotted to such scales and with a grid that will make it possible to read the data accurately.

f. The following information shall be imprinted on each theoretical and actual performance curve:

(1) Project title.

(2) Contractor's name.

(3) Name and address of fan manufacturer.

(4) Authority's fan designation number.

(5) Fan speed in revolutions per minute.

(6) Volume of air delivered in cubic feet per minute.

(7) Fan static pressure in inches of water.

(8) Fan total pressure in inches of water.

(9) Fan outlet velocity pressure in inches of water.

(10) Fan outlet velocity in feet per minute.

(11) Fan static efficiency in percent.

(12) Fan total efficiency in percent.

(13) Fan-motor unit total efficiency in percent.

(14) Motor efficiency in percent at operating point.

(15) Horsepower input to fan impeller.

(16) Kilowatt input to motor.

(17) Air density in pounds per cubic foot.

(18) Fan housing diameter in inches.

(19) Fan outlet area in square feet.

(20) Fan rotor hub diameter in inches.

(21) Number of fan blades.

(22) Direction of airflow (forward or reverse).

(23) Design blade pitch angle.

(24) Rotational moment of inertia of fan rotor assembly in pounds per square foot.

(25) Maximum acceleration time required to start fan-motor unit from rest and accelerate it to operating speed, in seconds.

2. Theoretical fan motor performance curves shall cover the entire range of load conditions from no load to not less than 115 percent of full load.

   a. Composite curve for each size of motor plotted with abscissa as horsepower output and ordinates as:

      (1) Current in amperes.

      (2) Speed in revolutions per minute.

      (3) Efficiency in percent.

      (4) Power factor in percent.

      (5) Torque in pound-feet.

b. Composite curve for each size of motor plotted with abscissa as speed in revolutions per minute from standstill to synchronous speed and ordinates as:

(1) Motor current in amperes.

(2) Motor torque in pound-feet.

(3) Fan torque in pound-feet.

(4) Motor acceleration from standstill to synchronous speed in seconds.

c. Composite air-over motor curves for each size of motor plotted with abscissa as air velocity in feet per minute and ordinate as horsepower.

d. Motor Winding and Bearing Temperature Test: Time in minutes as abscissa versus temperature rise in degrees Celsius as ordinates when operated at full voltage and speed.

e. Insulation Resistance-Temperature Test: Test result values shall be plotted on semi-logarithmic graphs, the insulation resistance values as logarithmic ordinates and the temperature values as uniform abscissa.

f. Also, for comparison purposes, a curve indicating the safe operating value of insulation resistance shall be plotted on the same sheet with the insulation resistance temperature test curve.

g. The following information shall be stated on each motor theoretical and actual performance curve and data sheet:

(1) Project title.

(2) Contractor's name and address.

(3) Name and address of motor manufacturer.

(4) Authority's fan designation number in which the motor forms a part.

(5) Motor type.

(6) Motor serial number.

(7) Motor frame size.

(8) Motor nameplate horsepower rating.

(9) Electrical characteristics (voltage-phase-frequency).

(10) Full-load and no-load current in amperes.

(11) Direction of rotation of motor.

(12) Speed in revolutions per minute.

(13) Service factor.

(14) Rotational moment of inertia of rotor in pounds per square foot.

(15) Electrical characteristics of space heater, including voltage and kilowatt input.

3. Fan-motor unit sound power levels in decibels (re: db 10^{-12} watts) shall be submitted as hereinafter specified (for both directions of airflow for reversible fans). Sound power levels in the eight frequency bands at design airflow capacity shall not exceed the listed values on the fan schedule shown at each octave band.

4. Manufacturer's quality assurance program in accordance with ANSI C1.

5. A complete list of projects on which similar fans for rail or transit tunnel projects in the United States have been applied. List shall include:

   a. Name of owner or user (include the Authority installations, if any).

   b. Contract number(s).

   c. Original installation date(s).

   d. Current condition of equipment.

   e. A list of all known failures for the past 10 years, including their apparent causes, corrective work effected (including design changes), and a description of equipment service and operating conditions.

6. List of components proposed to be purchased from other manufacturers, giving name of manufacturer, type and characteristic of each item and applicable data requested under Paragraphs 1 through 4 above.

B. Within 45 days after Notice to Proceed, Contractor shall submit the following:

1. Certified shop drawings including Bill of Materials for fans, motors, fan-motor unit bases, installation drawings, installation instructions, dimensioned drawings for anchor bolt locations, and any additional data required to demonstrate compliance with Contract documents. Shop drawings shall indicate weight of each component.

2. Certificate of Compliance signifying that equipment to be furnished under this contract meets the requirements specified herein and for the fan inlet conditions shown on the drawings.

3. Comprehensive General Arrangement Drawings of fan-motor unit assembly including ductwork, flexible connections, sound attenuators, dampers, etc.

4. Drawing of fan blades and hub identifying index marks for setting blade angles.

5. Fan and fan motor monitoring instrumentation mounting details.

6. Working drawings indicating the size and location of each concrete foundation for the fan-motor units in the ventilation building, reinforcing bar requirements for these foundations and the expected static and dynamic forces and moments generated by the equipment.

7. Contractor shall submit manufacturer's certificate of compliance signed by an officer of the company, and calculations or test results of previous elevated temperature tests conducted on a fan-motor unit of similar design and within plus or minus 10 percent of size and capacity if conducted for certification. The submitted data shall verify that the fan-motor units to be furnished for this contract are capable of operating for not less than 1 hour in an ambient temperature of not less than 482 degrees Fahrenheit (250 degrees Celsius). Manufactuer shall perform elevated temperature tests for all motors more than plus or minus10 percent of the size and capacity of the motors being provided for this project.

8. Submit basis and justification for material selection for fan blades and hub. Submit data on mechanical properties of the fan blades and hub and data on fan blade and hub yield strength at 482°F (250 degrees Celsius). Submit calculations to confirm that the blade stress does not exceed 60 percent of the component material yield strength at 482 degrees Fahrenheit (250 degrees Celsius).

9. Submit calculations taking into account the differential rates of expansion of dissimilar materials, showing the clearance of the blade tips to the fan housing. The fan manufacturer shall submit a table showing the maximum and minimum blade tip clearance at 0, 60, 100 and 482 degrees Fahrenheit.

10. Data sheet on motor bearing lubricant, frequency of lubrication and amount of lubricant to be supplied during lubrication.

11. Factory and field test procedures.

12. List of technical support items specified and list of any additional support items required.

13. Terminal box and electrical wiring diagram of motor terminal box.

14. Furnish drawing of nameplates.

C. Within 14 days after successful completion of tests specified herein and of any additional tests conducted at the Contractor's own option, Contractor shall submit the following:

1. Certified test results for all fan and motor factory tests conducted. All test data shall be bound in one report. The test report shall be indexed and cross-referenced in an easily understood manner.

2. All records and results of non-destructive examinations made at completion of each examination.

3. Field test results

4. Radiographic inspection films.

5. Furnish drawing of each fan impeller indicating the fan blade number and weight of each fan blade and blade and hub x-ray numbers with the factory test report.

D. Operation and Maintenance Manuals

1. At least 30 days prior to shipment of the first fan-motor unit, the Contractor shall submit to the Authority for approval three copies of the maintenance manual which shall provide technical support for fan-motor unit maintenance. After approval of the preliminary submittal and having made all necessary corrections and amendments required, the Contractor shall provide the Authority with 20 additional copies of the approved dated maintenance manuals. One set of master camera-ready copy shall be included as one of the 20 copies to permit additional copies to be made. The master camera-ready copy shall be clearly marked as such on the outside. The manual shall provide a clear explanation of the theory, operation, and maintenance of the equipment accompanied by photos and schematic, wiring, and mechanical assembly diagrams, as required. The manual shall be indexed and cross-referenced in an easily understood manner. The manual shall be loose-leaf bound and shall include, but not necessarily be limited to, the following information:

   a. Troubleshooting and fault isolation procedures for on-site level repair.

   b. Fan and motor removal and replacement procedures, including instructions on aligning motor and fan impeller in fan housing.

   c. Fan and motor removal and replacement procedures, including instructions on aligning motor and fan impeller in fan housing.

   d. Fan and motor disassembly and re-assembly instructions.

   e. A list of the components which are replaceable at the three possible levels of maintenance: on-site, The Authority's shop, and the Fan Manufacturer facility.

   f. A test procedure to verify the adequacy of repair work.

   g. A preventive maintenance schedule and instructions detailing lubrication of moving parts and monitoring of sound and vibration levels.

   h. Procedures for separately removing and replacing motor, fan rotor, and blades as well as procedures for removing a complete fan-motor unit without disassembly.

   i. A list of special tools provided by the fan manufacturer.

   j. Heavy gauge mylar template for blade angle setting for each fan.

   k. A list of tools and test equipment required to perform all maintenance tasks.

   l. Approved shop drawings.

m. Fan and motor factory test reports.

n. Field testing procedures and list of required equipment.

o. A list of parts to be replaced and/or testing procedures to determine parts to be replaced after a fan has been exposed to not less than 482 degrees Fahrenheit (250 degrees Celsius) for not less than one hour as specified, to allow fan and motor to be put back in service safely and reliably.

p. The latest service bulletins with dates which describe service procedures.

q. The Contractor shall notify The Authority of any revision to service bulletins which are included in the maintenance manuals described herein for a period of 2 years from the date of equipment acceptance.

E. Technical Support Items: At least 30 days prior to shipment, Contractor shall submit to the Authority the following:

1. Ten sets of special tools shall be provided in total. Special tools shall be those tools which are required to specifically service or repair the fan unit which is being supplied and which are not normally carried in a general machinists tool box.

2. Tabulation of technical support items necessary to maintain the fans procured under this Contract. This table will become a working document to be used by the Authority in the procurement of support items, and shall be updated as changes occur. The technical support items shall be grouped by equipment and components. This list for each item shall give complete ordering and procurement information for that item, including quantity required to maintain inventory for 200 hours operation. Each item listed shall contain at least the following information: item name, description rating, estimated operating life, current price, manufacturer's name, part name, and drawing reference number. Items that are common to more than one fan shall be cross-referenced. A column, immediately after the columns indicating recommended spare quantities, shall indicate expected delivery time in excess of 60 days.

F. Templates for Setting of Blade Angles: The Contractor shall provide at least two mylar templates or other approved devices for each fan to facilitate settings of blade angles in the field. One template shall be provided attached to each fan unit in a location which is subject to the Engineer's approval. One template shall also be provided with each maintenance manual.

PART 2 - PRODUCTS

2.01 FAN-MOTOR UNITS

A. Description

1. Fans shall be axial-flow type with reversible operation. Emergency fan-motor units shall be required to operate in the forward or reverse direction of airflow, with a capability of starting, stopping, or reversing the direction of flow at any time.

2. Fan-motor units shall be direct-driven by internally mounted electric motors, with provision for manual adjustment of the pitch of the individual blades, i.e., blade angle setting, or stagger angle. Fan-motor units and their supports shall be designed and constructed for the arrangement shown on Contract Drawings.

3. Motors shall be the product of a single manufacturer, whose name shall appear on the motor performance curves and other data submitted. The motors shall conform to all applicable ANSI, IEEE, and NEMA. Motors shall not be provided with self-contained thermal protective devices.

4. Motors shall be of the totally enclosed, air-over (TEAO), cast iron or steel round frame, induction type, continuous duty, variable torque, and shall be flange, pad, or foot-mounted. Motor nameplate rating shall be 460-volt, three-phase, 60 Hertz. Motor service factor shall be 1.15.

5. Nameplate horsepower shall be actual continuous brake horsepower developed without any consideration of the "air-over" factor.

B. Operating Environment

1. Fans and all parts thereof shall be capable of withstanding the effect of all stresses and loads under starting, operating, and reversing conditions specified. Fans and all components shall be capable of operating for not less than 1 hour in an ambient temperature of not less than 482 degrees Fahrenheit (250 degrees Celsius). Fans, motors and components shall be capable of withstanding sudden temperature changes, as a result of fire, between the extremes of 0 to 482 degrees Fahrenheit (minus 18 and plus 250 degrees Celsius) or vice versa in a time frame of 20 seconds during fan reversal. Contractor shall submit maximum design stress of rotating components at maximum fan speed and 482 degrees Fahrenheit (250 degrees Celsius) Temperature and shall designate types of materials to be used in design by their ASTM designations or approved equal.

2. Fans shall be designed and built to serve an underground subway environment and to function under conditions of high humidity and high temperature and the inlet and outlet conditions indicated.

C. Fan-Motor Unit Design Requirements

1. Fan-motor unit performance shall be rated for the airflow and total pressure specified on the Contract Drawings at a air density of 0.086 pounds per cubic foot.

2. Fan performance curves for either direction shall rise continuously with decreasing flow between free delivery and 60 percent of free air delivery or to maximum horsepower rating. Fans shall be capable of operating continuously at specified design points for forward and reverse flow. For the purpose of this Contract, forward flow shall be designated as exhaust mode (airflow from tunnel to atmosphere) and reverse flow shall be designated as supply mode (airflow from atmosphere to tunnel).

3. Emergency fan-motor units shall have a total efficiency of not less than 60 percent in forward flow and not less than 50 percent in reverse flow, when operating at the specified nominal flow rate.

4. Fans shall be capable of starting from a standstill to full speed, in not more than 15 seconds, without failure of any part of the unit. Fans shall be capable of reversing to full speed from either direction of airflow and rotation during an emergency within 20 seconds, after a 10-second delay between power interruption and the energizing of the motor for the reversed rotation, without failure of any part of the unit.

5. Emergency fan performance, when operating in the reverse direction of airflow and against a constant equivalent orifice, shall not deviate by more than ten percent in airflow delivered from the fan-motor unit performance curves for operation in the forward direction of airflow at any point between 60 percent of the nominal airflow rate and free delivery.

6. Brake horsepower input to fan impeller shall not exceed the nameplate horsepower rating of the fan motor when operating in either direction of airflow.

7. Pressure variations of plus or minus 1.25 inches water gauge induced by external causes shall not result in movement of the fan operating point along the fan operating curve into the region of unstable operation. This requirement does not affect the horsepower requirement for the design operating point.

8. Fans shall not operate in stalling range of fan performance curve during parallel operation (forward or reverse direction).

9. Fans shall have a stable operating characteristic in both directions of free flow over the range from 50 percent nominal flow of free delivery.

10. Fan motor unit sound power levels in decibels (re: db 10^{-12} watts) shall be submitted as hereinafter specified. Sound power levels in the eight frequency bands at design airflow capacity shall not exceed the listed values shown on the fan schedule at each octave band in either Exhaust (forward) or Supply (reverse) modes of operation.

11. No blade or wheel impeller assembly shall have a natural frequency within plus or minus 10 percent of two and three times operating frequency or at blade pass frequency defined as "number of blades times natural operating frequency."

2.02 FAN FABRICATION

A. Impeller hub and blades shall be fabricated of aluminum alloy castings, aluminum alloy forgings or steel, suitable for the specified performance and environment. Fan rotating components shall be designed such that no measured or calculated stress level shall exceed 60 percent of the components materials yield strength at design temperature (482 degrees Fahrenheit). Fan blades shall not vary in weight by more than 2 percent. Blades shall be manufactured of a homogeneous material as specified herein and shall have no cast-in or embedded materials of any kind. Individual blades shall be secured to the hub by not less than four bolts per blade, or shall be clamped securely between the two halves of a split hub or between suitably designed and manufactured clamp plates. Blade bolts, hub bolts or clamp plate bolts shall be readily accessible. The pitch of the blades shall be manually adjustable without removing impeller from fan unit. (Pitch is defined as the angle formed by the chord line of a blade root cross-section and a line parallel to the direction of rotation.) The ratio of the hub diameter to the fan housing diameter shall not be less than 0.35. The hub shall have index marks embossed or engraved to show the design operating blade setting and the blade settings for a minimum of five additional increments of stagger angle with not less than two on each side of design setting. In addition, the Contractor shall provide metal templates or other approved devices to facilitate settings of blade angles in the field. One template shall be provided attached to each fan unit.

B. Emergency fan housings, including motor mounts and motor supports shall be fabricated of hot-rolled steel not less than 1/4-inch thick. Clearance between housing inner diameter and blade tips shall be sufficient to allow for thermal growth difference between fan blades and fan housing at upset temperature of 482 degrees Fahrenheit (250 degrees Celsius). Fan housing shall be provided with split joints except for impeller section as shown on drawings, bolted, and gasketed to facilitate disassembly and removal of motor, rotor, shaft and bearings without removal of entire fan-motor unit or any part of adjacent ductwork. Welds located in the air stream shall be ground smooth. Flanged rings shall be continuously welded to the outer periphery at each end of the housings, or flanges may be rolled as part of the housing. Flanges shall be not less than 3 inches wide and not less than fan housing thickness. Flanges shall have punched or drilled holes equally spaced not more than 6 inches on centers to permit adjacent duct elements to be bolted to the housings. Provide remote lubrication fittings for lubrication of motor bearings from easily accessible location, as approved by the Engineer.

C. The rotor assembly shall be fastened to the motor shaft by means of an approved keyed positive locking device that is fully effective for both directions of rotation, for all blade angle settings, and for all conditions of operation specified. The rotor assembly shaft shall be an extension of the drive motor shaft.

D. Motor mounts and motor supports shall be designed to support the entire weight of the impeller and the motor, and to maintain the alignment of the fan-motor unit assembly in the specified mounting position and to maintain vibration levels within the specified limits. Motor supports shall be sufficient in number to provide the required strength and rigidity and shall be continuously welded to the motor mount and to the fan housing. Fan motor and fan rotor assembly shall be totally enclosed within the fan housing and not protrude at either end of the fan housing.

E. Nosepiece cover plates, access doors, hatch covers, and aerodynamic separation plates, where provided, shall be secured by means of positive fastening devices which are fully effective for

both directions of impeller rotation, for all blade settings, and for all conditions of operation specified herein.

F. Emergency fan-motor unit assembly supports shall be of carbon steel not less than 3/8-inch thick. Supports for horizontally floor-mounted fans shall include fan-motor unit structural steel base with vertical supports extending from the base to the fan housing centerline flange and with horizontal thrust plates extending over the full length of the fan housing. Vertical supports and thrust plates shall be welded continuously to the surfaces with which they come into contact.

G. Contractor shall provide a ¼-inch thick silicone gasket between all adjacent companion flanges; width of gasket shall be same as flange width. Gaskets shall be capable of withstanding an ambient temperature of not less than 482 degrees Fahrenheit (250 degrees Celsius) for not less than 1 hour without degradation of sealing ability and without emitting toxic or noxious fumes.

H. Sufficient lifting eyes shall be provided on each fan assembly to facilitate on-site installation and removal of the fans.

2.03 MOTOR COMPONENTS AND CONSTRUCTION

A. General Requirements

1. The motors shall be designed for continuous operation for a period of not less than 1 hour at an ambient temperature of not less than 482 degrees Fahrenheit (250 degrees Celsius).

2. Motors shall be equipped with factory installed resistance space heaters within the motor enclosure to prevent condensation of moisture in the motor windings. The heaters shall be energized whenever the motor is not in operation and shall be automatically de-energized whenever the motor is in operation. Heaters shall be 480 volts, single phase. The heaters shall be provided with leads terminated in the terminal box described in Paragraph 2.03 B.5, external to the fan housing. Motor space heaters shall be energized within 24 hours after the unit is delivered to the site.

3. Motor horsepower shall be as indicated on the nameplate. Horsepower input required by the fans shall not exceed the nameplate horsepower of the motors at any point on the fan performance curve in either direction of airflow. Motors shall have a minimum overall efficiency of 90.0 percent at the rated load. The locked rotor torque shall not be less than 145 percent of the motor full load torque and the locked rotor current shall not exceed six times the full load current with rated voltage and frequency at the motor terminals.

4. Motors shall be capable of accelerating the fan impeller from standstill to rated rotational speed in not more than 15 seconds after being energized with rated voltage and frequency at the motor terminals. Motors shall also be capable of decelerating the fan impeller after being de-energized and after a ten second delay between power interruption and accelerating to rated rotational speed in the opposite direction in not more than 20 seconds after being energized for reverse rotation.

5. Motors shall be rated in accordance with NEMA Standards for the locked rotor input (kilovolt-amperes per horsepower) required to meet the specified acceleration performance. Motor and shaft shall be designed for full plug reversal. Motors shall have a minimum of

Type H insulation and shall be rated for Class F temperature rise when tested at the service factor load as a minimum requirement. Motor service factor shall be 1.15.

6. Each motor bearing for tunnel ventilation fans shall be provided with a shock pulse measuring bearing damage detector for continuous remote monitoring of bearing. The detector shall be permanently encapsulated, coated electronics using microprocessor digital circuitry, with transducer. The accuracy of the detector shall be a maximum of 20 percent of detector level within temperature range. The detector shall be wired to an instrument panel containing circuitry and transducer, etc., to provide a normally open (n.o.) dry contact for remote alarm and/or indication at set point. The cables shall be approximately 30 feet long to allow connections to the instrumentation panel to be mounted remote.

7. Motors shall be provided with three built-in snap disc type thermostats with normally open contacts wired to the terminal box described in Paragraph 2.03 B.5 on the external to the fan housing for remote indication of excessive running temperature during normal operation. These wires shall be taped and terminated in the junction box.

8. Motors shall be provided with a minimum of six (two per phase) resistance temperature detectors (RTD's) and wired to an instrumentation panel described in Paragraph 2.03 A.6 on the external to the fan housing for remote indication of excessive running temperature during normal operation. The connecting cables shall be approximately 30 feet long. These wires shall be taped and terminated in the instrumentation panel. The electronics required to interpret the RTD signal and generate an alarm for each phase shall be included in the instrument panel.

9. During continuous operation, motors shall be insensitive to line voltage variation of ten percent above or below the rated voltage and to normal frequency variation. Motors shall be able to accelerate to full speed at rated load with starting voltage (dip) of 25 percent below rated voltage of the motor.

10. Motors shall be provided with magnetic induction type of speed switch, with normally closed contacts which will open when motor speed reaches a pre-selected value in either direction. Operating set point shall be adjustable by means of external adjusting screws. Unit shall be wired to the remote instrumentation panel described in Paragraph 2.03 A.6, external to the fan housing.

11. Minimum power factor of motors shall be 85 percent of the high speed winding at the rated load.

12. The motor shall be designed for accelerating fan impeller from standstill to operating speed without exceeding the rated temperature rise.

13. The motor shall be single winding. The starting and accelerating torque on motor windings shall be sufficient to permit the motor rotor and fan impeller to attain full winding speed without tripping the motor controller overload relays, which shall be set at a current corresponding to 140 percent of the motor full load current.

B. Motor Materials and Components

1. Motor shafts shall be steel, designed and constructed to support and drive the fan impeller under all specified operating conditions.

2. Motor starters and controls shall be furnished under the electrical section.

3. Each motor shall have at least two ball or roller type grease lubricated, electric motor grade, noise-tested bearings selected for the specified operating conditions of the fan motor unit. The bearings shall be based on AFBMA 9 or 11 and shall have a minimum L-10 life rating of 40,000 hours at maximum capacity and maximum speed based on the bearing load imposed by driven equipment.

4. Grease supply and relief lines shall be brought from each motor bearing to accessible lubrication fittings, external to the fan housing, accessible from the floor level of the fan room as approved by the Engineer. The lines shall not be less than 1/4-inch in diameter and shall be fabricated of stainless steel or other corrosion resistant alloy, seamless metallic tubing. The tubing shall not be crushed or scored during installation and the lines shall have neither kinks nor sharp bends. Lines penetrating the housing shall be rigidly secured to the housings to prevent vibration of the lines and be provided with grommets. Grease supply lines shall terminate in straight lubrication fittings. Grease fittings shall only allow the proper amount of grease to each bearing. The bearing lubricant shall be capable of providing the lubrication properties specified by the bearing manufacturer under conditions of operation for 1 hour with the lubricant at a temperature of 482 degrees Fahrenheit (250 degrees Celsius) and also at a temperature of 0 degrees Fahrenheit (minus 18 degrees Celsius).

5. The motor leads shall be of cable, suitable for not less than 1 hour at not less than 482 degrees Fahrenheit (250 degrees Celsius), wired to a gasketed NEMA 12 terminal box mounted externally to the fan housing. The terminal box shall have screw type pressure terminals strips for terminating control wires, exterior mounting lugs, full cover gasket, hinged door, minimum inside dimension of 24 inches high by 24 inches wide by 12 inches in depth. The conduit and terminal box shall be rigidly secured to the fan housing in a manner which will prevent vibration and air leakage and shall be capable of withstanding not less than 482 degrees Fahrenheit for not less than one hour without causing fan failure. Terminal box shall be capable of being oriented to receive feeder conduits from any direction. Terminal box shall also be capable of receiving the number and size of conduits as shown on the electrical drawings. Motor terminals and connectors shall be as described in the DIVISION 16. Motor leads shall be installed to avoid interference with control leads and terminal strips. Sufficient cable slack shall be provided to permit testing of cables without disconnecting any connections.

6. Lifting lugs shall be provided on the exterior of motors.

2.04 SHOP FINISHES

A. After fabrication and prior to assembly, all inside and outside surfaces of all fan housings, fan housing extensions, supports, fan-motor unit bases and exterior of fan motor shall be prepared in conformity to the requirements of SP-10 New White Blast Cleaning and shall be given a rust-inhibiting coating, which may consist of an approved plastic coating, or bonderizing, or

phosphatizing, followed by the application of a suitable rust-inhibiting primer and finish paint that is resistant to abrasion and to exposure to elevated temperatures. Surface finish shall be capable of withstanding:

1. An ambient temperature of not less than 482 degrees Fahrenheit (250 degrees Celsius) for not less than 1 hour without degradation of its protective quality, and without emitting toxic or noxious fumes.

2. Two hundred hours in salt spray fog test, in accordance with Method 6061 of Federal Test Method Standard No. 141. Immediately upon removal of the panel from the test, the film shall not show any visible blistering or rust spots, and there shall not be over 1/8-inch of rust creepage on either side of the scratch mark.

B. Provide colors conforming to Method A, Color Selection Made After Award of Contract.

C. Surface finishes damaged during transport or assembly shall be restored to their original condition and color by the installing contractor.

2.05 HARDWARE

A. Fasteners

1. In accessible areas, fasteners shall be hexagonal nuts, provided with heavy-duty lock washers.

2. In inaccessible areas, fasteners shall be hexagonal head tap bolts, provided with heavy-duty lock washers.

3. Bolts shall not be less than 1/2-inch in diameter unless otherwise indicated.

4. Bolts and tap bolts shall be stainless steel and shall conform to the requirements of ASTM A193, Grade B8M or B8MA, equivalent to AISI Type 304, with suitable lock washers.

5. Nuts shall be stainless steel and shall conform to the requirements of ASTM A194, Grade 2H, equivalent to AISI Type 304.

6. Galvanized steel bolts, nuts and lock washers shall be used on galvanized components. The bolts shall conform to ASTM A325, Type 1 galvanized; the nuts shall conform to ASTM A563, Grade DH galvanized; and the lock washers shall be galvanized steel per ANSI B18.21.1.

B. Anchor Bolts:

1. Anchor bolts shall be stainless steel and shall conform to the requirements of ASTM A193, Grade B8M or Grade B8MA, equivalent to AISI Type 316, with suitable lock washers.

2. Anchor bolt nuts shall be stainless steel and shall conform to the requirements of ASTM A194, Grade 2H, equivalent to AISI Type 316.

2.06 NAMEPLATES

A. Each fan shall be provided with a stainless steel nameplate permanently stamped with the name and address of the manufacturer, Contractor's identification number, fan type, Authority-designated fan number, shop order, serial number of fan, year of manufacture, maximum safe operating speed of fan in revolutions per minute, fan impeller diameter, maximum design operating speed and corresponding volume of air delivered and the fan total pressures at density specified. The nameplate shall be securely screwed or riveted to the exterior of fan housing in a conspicuous position.

B. Each fan shall be provided with a stainless steel enamel plate which shall bear, in numerals not less than 3-inches high, the Authority fan designation numbers. The plate shall be securely screwed or riveted to the exterior of the fan housing adjacent to the fan nameplate.

C. Each motor shall be provided with two identical stainless steel nameplates permanently stamped with the name and address of the motor manufacturer, the motor horsepower, voltage, phase, frequency, insulation type, full-load current, locked rotor indicating code letter, minimum overall efficiency, the design temperature rise over ambient of the motor, type of duty, the terminal connection chart for the motor, rating of space heater, speed in revolutions per minute, service factor, motor type and serial number, bearing numbers and shop order number. One nameplate shall be furnished on the motor and the other either riveted or screwed on the exterior of the fan housing immediately adjacent to the fan nameplate.

D. Each fan shall be provided with a 10-inch long by 1-1/2-inch wide metallic arrow which shall indicate the direction of forward and reverse airflow. The arrows shall be rigidly and permanently attached to the fan housing, in a position which can be readily viewed when the fan is in its final operating position. Three-quarter-inch letters shall be engraved on the arrow to read as follows: "EXHAUST (FORWARD AIRFLOW)" and "SUPPLY (REVERSE AIRFLOW)."

E. Each fan shall be provided with a 10-inch-long by 1-inch-wide stainless steel plate permanently stamped with the labels "Grease Line Supply Port" and "Grease Line Exit Port".

F. All the nameplates shall be 316 stainless steel not less than 10-gauge thick and shall be placed so as to be readily conspicuous after installation.

2.07 REVERSE AIRFLOW SWITCHES

A. Tunnel fans shall be provided with a reverse airflow switch. The flow switch shall have the capability to detect flow in either direction.

B. The reverse flow switch/monitor shall have no moving parts. It shall utilize thermal dispersion as a means for detecting the presence and direction of the air flow. The flow switch shall be capable of being field set from 1 to 40 feet per second velocity in air. Repeatability shall be 1 percent of full signal range. Maximum sensor temperature rating shall be not less than 482 degrees Fahrenheit. Maximum electronics rating shall be 140 degrees Fahrenheit.

C. The flow switch sensor shall be 316 SS, nickel brazed material. The sensor shall have 1 1/4-inch NPT connection and a 12 inch insertion length.

D. Remote electronics shall be provided, without enclosure, for installation in instrument panel. Fifteen feet of interconnecting cable shall be included with each switch. The probe terminal strip enclosure shall be NEMA 4 and NEMA 7 BCD compatible. Two DPDT relays rated for 2 amps at 120 VAC shall be provided, one for each flow direction.

E. The flow switch shall be FM or UL approved.

F. A factory authorized service technician shall verify installation and adjust flow switch set points after installation is complete.

G. Flow switch shall be provided with Form "C" dry contacts, two for each direction of air flow.

2.08 FACTORY TESTS AND INSPECTIONS

A. General

1. The Contractor shall perform factory tests as described below. The Authority's representatives may, at their option, witness any or all tests. The Contractor shall pay for all travel, lodging and meal expenses for three (3) representatives of the Authority to attend the factory witness testing of the tunnel ventilation and the motor control center. Observations made during the tests and all test results shall be recorded in a document form, certified by the Contractor and submitted to the Authority for approval. Three weeks notice and information as to proposed test procedure shall be furnished to the Authority prior to the factory tests.

2. Tests described herein shall not preclude additional standard tests normally performed by the manufacturers for similar equipment.

3. Pre-production fan-motor units used for testing may be furnished as production units after pre-production testing if the units satisfactorily pass all specified factory tests as described below under production fan tests.

4. The test procedures specified herein shall be sequential in the order prescribed. Any fan-motor unit or component thereof which fails to satisfactorily perform any test as specified shall be considered unacceptable. Failing parts shall be replaced and the entire unit shall be re-tested as specified herein.

5. Before actual testing is begun on any ventilation fan-motor unit to be furnished, Contractor shall submit full details of all test procedures including the sequence in which they are to be run and the expected duration of the test, samples of all test report forms, and full details of the methods by which the raw test data is to be reduced for submittal to the Authority for approval.

6. Test details shall also include a list of test instrumentation, containing name of manufacturer, model type, serial number, and calibration date. Documentation shall be furnished to verify that test instrumentation has been calibrated not more than 9 months prior to the tests.

7. Tests shall be performed by the Contractor at the fan manufacturer's plant or other Commission-approved location.

8. All expenses in connection with or incidental to the factory testing shall be borne by the Contractor.

B. Motor Tests

1. Motors shall be tested in accordance with the procedures specified in IEEE Publication 112 and NEMA MG-1. A certified test report and certified performance curves verifying the theoretical motor performance curves for all of the coordinates specified shall be submitted to the Authority for approval. Performance curves for each type and size of fan motor shall be plotted to a scale which will facilitate accurate readings.

2. One motor of each nameplate horsepower rating and service factor shall be tested for forward and reverse modes as follows:

   a. Tests to obtain actual fan motor performance curves verifying the theoretical fan motor performance curves previously submitted and other data specified hereinafter.

      (1) Full-load current in amperes

      (2) No-load current in amperes
      (3) Full-load input in kilowatts

      (4) No-load input in kilowatts

      (5) Locked-rotor current in amperes

      (6) Locked-rotor input in kilovolt amperes

      (7) Locked-rotor torque in foot pounds

   b. Tests to determine:

      (1) Winding resistance

      (2) Losses, no-load and full-load

      (3) Temperature rise

   c. Dielectric tests

   d. Visual bearing inspection

3. The remaining motors shall be tested at its rated synchronous speed unwitnessed. Reversible motors shall be tested in one direction. Tests shall include the following:

   a. Winding resistance

   b. No-load current in amperes

   c. Dielectric tests

d. No-load speed

e. Visual bearing inspection

f. Locked rotor current in amperes

4. The following data shall be plotted for each direction as ordinates versus horsepower as abscissas up to not less than 115 percent full load:

a. Current, in amperes

b. Efficiency, in percentage

c. Power factor, in percentage

5. The following data shall be plotted for each motor frame size as ordinates versus revolutions per minute as abscissas:

a. Current in amperes

b. Torque in foot-pounds

c. Power factor in percentage

6. Test data for the certified performance curves shall be recorded at the rated voltage and frequency of the motor, continuously over the speed range from standstill to rated rotational speed of the motor.

C. Non-Destructive Inspection

1. Radiographic Inspection

a. Provide a certification that, for all fan hubs and blades, x-rays have been taken, with notation of the x-ray numbers, and also that zyglo testing has been performed. In addition, provide a complete list of the identification numbers for all hubs and blades actually installed in each fan.

b. Certification of visual acceptability, the x-ray procedure, the x-ray films, and proof of traceability of conformance with alloy specifications of the metal used to cast the hub and blades shall be submitted to the Engineer for approval. The identification number of the x-ray film shall be etched on each blade and hub at a location which will not create adverse stress concentrations to reduce the design safety factor at the point of critical stress.

c. The x-ray films shall be kept on file by the manufacturer for a minimum of 5 years.

2. Ultrasonic Examination

a. Provide certification that, for all forged fan hubs and blades, ultrasonic examination has been performed in accordance with ASTM A388. In addition, provide a complete list of the identification numbers for all hubs and blades actually installed in each fan.

b. Certification of visual acceptability, the ultrasonic examination procedure, and proof of traceability of conformance with alloy specifications of the metal used to forge the hub and blades shall be submitted to the Engineer for approval.

c. The ultrasonic examination results shall be kept on file by the manufacturer for a minimum of 5 years.

D. Overspeed Tests

1. All fan rotor assemblies manufactured and furnished for this Contract shall be subjected to an overspeed test at the factory as specified herein prior to assembly of the complete fan-motor units.

2. After non-destructive inspection and after static and dynamic balancing, each completely assembled fan impeller shall be overspeed tested in both directions. Spin testing of individual components, such as blades and rotors, in lieu of testing complete impellers, is not acceptable. Each fan impeller shall be spun from standstill up to 125 percent of the maximum design operating speed for a period of not less than 3 minutes. Following each spin test, a visual inspection for surface defects shall be made by the Contractor. Certificates of visual acceptability shall be submitted to the Authority for approval.

E. Vibration Test

1. After assembly, each fan-motor unit shall be checked for bearing operation in both directions of rotation. Defective bearings shall be replaced, and the fan shall be re-checked before further testing. The vibration shall be measured in two radial planes, 90 degrees apart, and in the axial direction. Measurements shall be made for each radial plane at the front and rear of the fan. Measured maximum vibration shall not exceed peak-to-peak amplitudes of 1.2 mils (0.0012-inch) for fans operating at a nominal speed of 1,200 revolutions per minute or less.

2. If measured vibration amplitude exceeds the specified maximum, or if the specified vibration measurements reveal unacceptable vibration at any frequency other than rated design operating speed, vibration amplitude shall be measured and recorded continuously as the fan is accelerated from a standstill to rated design operating speed, and as the unit coasts down from rated design operating speed to a standstill. The amplitude versus frequency chart shall be analyzed by the Contractor (Fan Manufacturer) to determine the cause(s) of the unacceptable excessive vibration. Resonant frequencies shall be determined and shall be demonstrated as not to occur within fan operating ranges. The analysis shall be submitted to the Authority for approval and the cause(s) shall be corrected. The Authority shall be furnished final vibration amplitude readings on all fan bearings.

F. Fan-Motor Unit Performance Test

1. One pre-production fan-motor unit which has satisfactorily passed the preceding test and inspections specified, shall be tested in accordance with the procedures specified in the AMCA 210, latest edition, using a test set-up approved by the Authority.

2. Fans shall be tested without flow cones or any other static regain devices. The fans shall be tested at the blade angle which shall produce the required volume of air at the required system pressure. This blade angle shall not be at its maximum setting. Test data shall be recorded on AMCA data submittal forms, or the equivalent thereof, as approved by the Authority. Certified test data, and certified performance curves for all of the coordinates specified shall be submitted to the Authority for approval.

3. Performance tests shall cover the range of airflow rates from no flow to free air delivery. Performance tests of emergency fans shall cover this range of airflow rates in both directions of airflow. Actual fan performance shall not be less than contract values.

4. The fan shall be calibrated for airflow capacity versus annulus velocity, using laboratory grade pitot tube in the annulus and mounted through the bushing in the fan housing during performance test.

5. Triaxial Strain gauges shall be applied to two blades per impeller and to the hub of the unloaded impeller of each fan. To accurately measure strains and stresses developed in each rotor, one strain gauge at the midpoint and one strain gauge at the tip of blades on each side shall be applied on minimum of two blades. In addition, one strain gauge shall be applied on impeller hub for each strain gauged blade. The strains developed during performance testing shall be continuously measured and monitored. The measured strains produced under the performance test load shall be used to calculate the corresponding stresses. Stresses found shall not exceed sixty percent of the material yield strength at 482°F. The methods of strain measurement and stress calculation shall be submitted to the Engineer for approval. The Contractor shall submit the manufacturer's notarized certification that the measured strains and the corresponding calculated stresses represent the strains and stresses developed in all other blades of the pre-production fan motor unit being tested. Calculated maximum expected stresses, and the design properties of the material used to fabricate the impeller blades and hub, shall also be submitted to the Engineer for approval. Strain gauge testing shall be performed using the same testing set-up and operating conditions as the fan full scale performance test.

6. In the event that the tests show that the fan-motor units do not comply with the requirements as to characteristics and performance, or that the brake horsepower will exceed by five percent or more the brake horsepower shown in the theoretical data submitted by the Contractor, the fan-motor units will be rejected unless changes are made therein and tests repeated until the specific requirements are met.

7. Upon the completion of the fan-motor units performance tests, submit two complete copies of all raw test data.

8. After the completion of fan-motor units performance tests, submit for each fan-motor unit size, performance curves and tables of performance data calculated from shop test data, at each of the test points at each rotational direction.

9. The tables shall consist of numerical values at each of the test points for the following:

   a. Volume of air delivery in cubic feet per minute

b. Fan static pressure in inches of water

c. Fan total pressure in inches of water

d. Fan outlet velocity pressure in inches of water

e. Fan total efficiency in percent

f. Fan static efficiency in percent

g. Horsepower input to fan impeller

h. Fan speed in revolutions per minute

i. Current input in amperes

j. Voltage in volts

k. Motor power input in kilowatts and power factor

l. Number of phases and frequency

10. Submit fan-motor unit performance curves verifying the theoretical performance curves previously submitted. Test points shall be indicated on performance curves.

G. Noise Test

1. Pre-production unit which has satisfactorily passed all preceding tests and inspections specified shall be tested at the design duty on the performance test set up in accordance with the test procedure of ANSI 12.36 to obtain sound power level data at eight-octave band center frequencies from 63 Hertz to 8,000 Hertz.

2. Fan shall be tested with specified nominal airflow in both forward and reverse directions. Test data shall be submitted to the Authority for approval in tabular form.

H. Reversal Test

1. One fan motor unit which has satisfactorily passed all preceding tests and inspections specified shall be subject to reversal tests. These tests shall require operation at rated operating speed for approximately 3-1/2 hours with the unit oriented in the position that it will be installed, and shall require three cycles of rotation reversal. A cycle of rotation reversal is defined as reversal from one direction of motor impeller rotation to the other direction of rotation, and then back to the first direction of rotation.

2. The reversal test shall begin with the fan unit operated in the forward direction of airflow for a period of 30 minutes.

3. At the end of the first 30-minute period of operation in the forward direction of airflow, the motor shall be electrically reversed, with a 10-second time delay imposed between the interruption of power and re-energizing of the motor for reversed rotation.

4. After the motor has been re-energized, the fan shall be operated in the reverse direction of airflow for a period of 30 minutes.

5. The test shall be continued, with alternating 30-minute periods of operation in the forward and reverse directions of airflow, until six rotation reversals have been performed. At the end of each 30-minute period of operation, the fan-unit motor shall be electrically reversed, with a 10-second time delay imposed between each change in direction until six rotation reversals have been performed.

6. After three cycles of rotation reversal, i.e., six reversals of the direction of motor and impeller rotation have been performed, the fan-motor unit shall be operated for a period of 30 minutes.

7. At the end of the last 30-minute period of operation, the fan shall be de-energized, and permitted to coast to a standstill.

8. Resistance of the cold motor winding insulation shall be measured just prior to the start of the reversal test, and the motor winding insulation shall be measured immediately after the end of the test. In addition, the temperature of the motor windings and of the motor frame shall be continuously recorded throughout the test and the acceleration time, speed, voltage, frequency, amps, and kilowatts shall be recorded during each reversal. Certification of successful performance of the reversal test and certified test data shall be submitted to the Authority for approval.

I. Run-In Test

1. Each emergency fan shall be operated continuously for a total of 24 hours, 12 hours in the forward (exhaust) mode and 12 hours in the reverse (supply) mode of rotation. During reversal, fan shall be allowed to coast for a period of 5 minutes before being restarted in the reverse direction.

2.09 CONTROL SEQUENCING

A. Emergency Ventilation Fans: All emergency ventilation fans in a particular shaft shall be operable simultaneously at full speed in either the supply or exhaust mode for emergency ventilation from fire management panels or central control. Fans shall be capable of being tested (jogged), locally in either mode.

2.10 CONTROL AND INDICATION LOCATIONS

Function	(C) Control (I) Indication	Motor Control Center (MCC)	Operations Control Center (OCC)*	Fire Management Panel (FMP)	Local
Supply		C,I		X	X
Exhaust	C,I		X	X	
Stop		C		X	X
Off	I		X	X	
EF 1 Supply	C,I	X			
EF 1 Exhaust	C,I	X			
EF 1 Stop	C	X			
EF 1 Off	I	X			
EF 2 Supply	C,I	X			
EF 2 Exhaust	C,I	X			
EF 2 Stop	C	X			
EF 2 Off	I	X			
EF 1 Test - Supply	C	X			X
EF 1 Test Exhaust	C	X			X
EF 2 Test - Supply	C	X			X
EF 2 Test - Exhaust	C	X			X
Abnormal Operation	I		X		
Power Failure	I		X		
Fire/Smoke	I		X		
Intrusion	I		X		

Function	(C) Control (I) Indication	Motor Control Center (MCC)	Operations Control Center (OCC)*	Fire Management Panel (FMP)	Local
Motor High-Temp	I		X		

PART 3 - EXECUTION

3.01 INSTALLATION METHODS

A. All fans shall be furnished and installed as specified herein and as indicated on the Drawings. The manufacturer's rigging instructions shall be carefully followed. The Contractor shall make certain that the installation of all supports, gaskets, hardware, etc., are accomplished with precision and the exercise of extreme care so as to assure safe, accurate and trouble-free fan installation.

B. The fan installation shall be done in the presence of the Field Service Engineer.

C. Prior to proceeding with the work described above, the Contractor shall submit for the Engineer's approval eight copies of detailed drawings showing all fan installations including dimensions, supports, hardware, installation methods, and all other pertinent data.

D. Emergency fan-motor assembly shall be mounted and leveled using "stainless steel shim packs" as shown on the drawings.

E. Fans shall be connected to transition companion flanges with 1/4 inch thick solid silicone gasket between.

F. When installed, the orientation of each fan, as to motor end, shall be as indicated on the Drawings. Fans which are improperly installed shall be removed and reinstalled at the Contractor's expense.

G. Equipment shall be installed, leveled, and located so that working space is available for servicing, replacing, lubricating, and gaining access to controls.

H. After installation and before the start of testing, the equipment shall be lubricated. Equipment shall be checked for clearances and proper alignment.

I. Ventilation equipment shall be carefully protected at the site in a manner to preclude the possibility of damage to the equipment.

J. All power and control wiring external to the ventilation equipment shall be provided under DIVISION 16, ELECTRICAL. The permanent anti-condensation motor space heaters for the fan motors and the damper motors shall be energized with temporary power before and after installation until permanent power is available, as specified under DIVISION 16, ELECTRICAL.

3.02 FIELD SERVICE

A. The Contractor shall provide field service engineering and inspection to the Authority to ensure that the fans supplied herein are properly installed and tested.

B. Field service shall be performed periodically as required during the period of performance of the Authority's construction contracts.

C. The Authority shall be advised in writing of the name and title of the proposed field service engineer, who upon Authority approval shall have complete authority to represent and to act for the Contractor.

D. The duties, responsibilities, and qualifications of the field service engineer shall be:

1. Responsible for advising the installation contractors on the proper procedures for the installation of the fan equipment.

2. To have a thorough knowledge of the ventilation systems.

3. To have a thorough knowledge of the test results and performance requirements of all material and equipment supplied.
4. To prepare and submit to the Authority a typewritten report on the activities and findings for each visit made within fifteen working days of the visit.

3.03 FIELD TEST

A. Upon completion of the installation of the ventilation equipment at the fan room and the installation and verification of the power and local control wiring, the Contractor shall notify the Engineer in writing at least 2 weeks prior to the field testing to have the Engineer present to witness the tests. The Contractor shall also notify the Field Service Engineer for assistance in the performance of the tests. The Contractor shall furnish written instructions for testing of the fan motor units in the field. This instruction shall be submitted as a part of the operating and maintenance instruction.

B. Field tests shall be performed under the technical guidance and supervision of the Field Service Engineer. The Field Service Engineer shall provide the field test instrumentation and perform the tests. The Field Service Engineer shall measure and record the vibration amplitude; power consumption; no-load, starting and full-load voltages; starting and full load currents; and acceleration time.

C. Time of operational run in testing shall be 2 hours per fan; 1 hour in each direction for reversible (emergency) fans. Where multiple fans are installed in the same room, all fans shall be operating simultaneously when determining and recording the electrical measurement. Prior to the operational tests, the vibration and electrical measurements shall be recorded for each fan motor unit at design speeds in each direction.

D. Testing for the ventilation equipment shall not be undertaken until permanent electric service and local controls can be provided for testing.

E. Visual and operating tests required are as follows:

1. Each fan-motor unit shall be checked for obviously rough operation after the fans are installed. Defective bearings shall be replaced with new bearings and the fan(s) shall be re-checked. Amplitude and frequency of radial and axial vibrations at the bearings shall be measured, recorded, and checked for conformity to the Specifications.

2. Each fan-motor unit on which the specified vibration field tests have been successfully performed shall be tested to confirm that such fans are operational. Each emergency fan-motor unit shall be proven operational in both directions of airflow, including one reversing of direction of rotation.

3. When multiple fans are to start, starting sequence shall be provided with 20 seconds interval. All fans shall achieve full speed in 75 seconds. When all fans are to be reversed, fans shall be de-energized for 30 seconds. After 30 seconds, the selected fan shall be energized for reverse rotation with successive fans energized at 20 seconds .

4. Electricians to energize the ventilation equipment and make temporary connections where required and assist the Field Service Engineer during testing shall be provided by the Contractor.

5. Field measurements required are as follows:

   a. Airflow Performance Test

      At each fan chamber or shaft, after all construction and other work involving the air pathways has been completed and all fans have be installed and Run-In, a test to determine actual air output under operating conditions shall be made as specified below.

      (1) Each fan shall be tested at the design blade angle while all fans at the fan chamber(s) serving the particular location are operating simultaneously; for each fan, while under both supply and exhaust operation, the Contractor shall determine and record the power consumed using a precision, digital wattmeter: he shall simultaneously record the barometric pressure in inches Hg. and the D.B. temperature of the air passing through the fan. Based on the recorded data and in conjunction with the certified operating fan and motor data and curves derived from shop tests, the air delivery of each fan under both supply and exhaust conditions shall be determined for each of the operating conditions specified above: BHP shall be corrected to the air density of 0.086 pounds per cubic foot before use with the fan performance curves and all calculations shall be shown in the report.

      (2) If the air delivery of the fans is equal to or greater than the design output stated in the contract, no adjustment shall be made to the blade setting of the fans, except when the Engineer directs that air delivery be reduced due to higher than desired brake horsepower. However, if air delivery is less than the design output, the Contractor shall, with approval of the Engineer, adjust the fan blades in order to bring the air output of the fan to the design level (or as close as possible to the design level) without increasing the design BHP to more than 5% above the design BHP indicated on the Contract Drawings.

      (3) The contractor shall, following any change in air delivery of any fan, repeat the tests to determine actual air output of each of the fans which operate in parallel, with the

fans run under test for a minimum of 1 hour with 30 minutes each under supply and exhaust operation. Both the Engineer and the fan manufacturer's Representative shall be present at these tests. The Contractor shall promptly submit for the approval of the Engineer copies of the test results. The reports shall show all test results including those from initial and subsequent tests. The reports shall clearly indicate, with simple sketches, if necessary, the initial and subsequent blade setting of the fan.

b. The last portion of the field tests shall be the measurement of air movement within the tunnel produced by the ventilation system. These measurements shall serve as the verification that the ventilation system would produce sufficient air movement during a fire to satisfy emergency ventilation criteria.

c. These tests shall be performed by qualified personnel (employees of the Contractor or a subcontractor), who have been approved by the Engineer. The overall responsibility for this measurement program shall belong to the Contractor.

d. The Engineer shall provide the Contractor with details on two locations for the measurements, the testing conditions (such as ventilation system operating requirements and the location of stopped trains), and the test results required for each location at least 180 days prior to the scheduled date of test initiation. The entire tunnel cross section shall be traversed in order to measure the average airflow (in cubic feet per minute) through the cross section. The measurements shall be accurate to plus or minus five percent and shall account for the effects of the tunnel portals, changes in horizontal curvature, and location and distance from the stopped train. The Contractor shall make the necessary arrangements with the Authority to schedule the tests and to use a stopped train during the actual testing period.

e. The Contractor shall submit to the Engineer, for approval by the Engineer, a written test program at least 45 days prior to the scheduled date of test initiation. This test program shall contain, as a minimum, the resumes of the key personnel participating in the test phase, the specific make and model numbers of the test equipment to be used, and a general procedure to be followed for the set-up of equipment and for the sampling, recording, and reduction of the test data.

f. The Contractor shall provide the Engineer with the measured test results. If the Engineer determines that the measured air velocities are less than the required "cold" air velocities, the Contractor shall be notified in writing to increase the blade angles in order to produce the required tunnel airflow velocities. If the increased fan airflows cause overloading of the fan motors, the Contractor shall advise the Authority in writing on the extent of the overload. The Authority shall provide the Contractor with a written list of the appropriate equipment modifications that the Contractor shall be responsible to perform. The field measurements shall then be repeated in order to verify that the required tunnel airflows have been achieved.

g. The Authority shall be notified in writing at least 2 weeks prior to the initiation of this testing phase in order to coordinate the use of train(s) and to program the appropriate ventilation system operation.

6. Any defect that develops within the ventilation equipment during the test shall be corrected by the Contractor at no additional cost to The Authority.

7. Any defect that develops with the installation work during the test shall be corrected by the Contractor at no additional cost to The Authority.

F. After completion of all field tests and after the final visit by the field service engineer, Contractor shall submit a field test and inspection report. Field test report shall include copies of raw data, measured results, calculations, and all data derived from tests to confirm compliance with specified performance, noise, vibration and equipment efficiencies.

G. The Contractor shall energize the motor space heaters within 24 hours after the fan is delivered to the site.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. No separate measurement will be made for work required under this section but all costs shall be included in the pay item TUNNEL VENTILATION SYSTEMS which will be paid for on under a lump sum basis, complete in place including all terminations, relocation of existing feeders, testing, connections, staging, demolition and incidentals as shown on the Drawings and specified herein.

4.02 PAY ITEMS

ITEM NO.	DESCRIPTION	UNIT
1586.040	TUNNEL VENTILATION SYSTEMS	LS

-END OF SECTION-

SECTION 16050

BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK

PART 1 – GENERAL

1.01 DESCRIPTION

A. This Section specifies the basic materials and methods of installation applicable to electrical work, in accordance with MBTA Standard Specification Section 16050, except as modified herein.

B. The work specified in this Section consists of furnishing, installing, connecting and testing the following components and systems to be used in construction of this project.

1. Raceway Systems. Surface and embedded.
2. Handholes.
3. Boxes and Cabinets.
4. Wiring Devices.
5. Switches.
6. Lighting Fixtures.
7. Wire and Cable.
8. Bonding.
9. Motor Starters.
10. Empty Conduit System for Monitors.
11. Panelboards.
12. Emergency Generator.
13. Electric Unit Heaters (furnish only).
14. Telephone and Data.
15. Close Circuit TV.
16. Electronic Sign System.
17. Public Address System.

18. Elevator Pit Pump Wiring.

19. Modifications to Existing Fire Alarm System.

20. Signal Cable and Equipment – Protect in Place.

21. Low Voltage Automatic Transfer Switch

22. Train Annunciator System.

23. Meters and Distribution Cabinets.

24. Passenger Assistance Telephone System.

25. Heat Trace Cable.

26. Feeder Isolation Switches.

27. 1000 volt DC wire as approved by MBTA.

28. Double-Ended Unit Substations including Potheads at Maverick Station and Unit Substation B2.

29. Communication Programmable Language Controller Tunnel Ventilation System.

30. Remote Terminal Units.

31. Unit Heaters.

32. Motor Control Centers.

33. Tunnel Ventilation Shaft B3.

1.03 SUBMITTALS

D. Shop Drawings: Shall be submitted for the following:

1. Disconnect Switches, Motor Starters and Motor Control Centers.

2. Heat Trace Cable.

3. Lighting Fixtures.

4. Raceways.

5. Conduit Fittings.

6. Grounding.

7. Wires and Cables.

8. Panelboards and circuit breakers.

9. Transformers.

10. Wiring Devices and Cover Plates.

11. Outlet and Junction Boxes.

12. Conduit Hangers and Supports.

13. Low Voltage Transfer Switch.

14. Emergency Generator.

15. Closed Circuit TV.

16. Electronic Sign System.

17. Public Address System.

18. Passenger Assistance Telephone System.

19. Train Annunciator System.

20. Signal Cable and Equipment Protection Plan.

21. Bonding.

22. Feeder Isolation Switches.

23. 1000 volt DC wire.

24. Electric Heaters.

25. Unit Substations including Potheads.

E. As-Built Drawings

1. The Contractor shall keep one set of Working Drawings to maintain progress as-built drawings for bi-weekly review by the Authority. These prints shall be at all times absolutely clear and completely show the actual installations in accordance with the Contract requirements.

2. Upon completion of the work, the Contractor shall submit final "As-built" drawings. These drawings shall be prepared on AutoCAD Version 2002 software standards and drawing sizes shall conform to MBTA standards. "As-built" drawings shall be printed on four-mil-thick double matte mylar film. A CADD disk containing final "As-built" drawings shall also be submitted.

3. The Contractor shall update the existing MBTA plans and shop drawings as indicated herein.

F. Coordination Drawings. See Section 16070, SUBMITTALS, Page 16070-3, Paragraph 1.04 for requirements for Coordination Drawings for mechanical and electrical work.

1.04 REGULATORY REQUIREMENTS

3. American National Standards Institute (ANSI) Publications

4. National Electrical Manufacturer's Association (NEMA) Publications

5. National Fire Protection Association (NFPA) Publications

6. American Iron and Steel Institute (AISI) Publications

7. American Society for Testing and Methods (ASTM)

8. Underwriter's Laboratories, Inc. (UL) Publications

9. Board of Fire Prevention Regulations

10. Electrical Industries Associates (EIA)

11. Telecommunication Industry Associates (TIA)

12. City of Boston

13. Commonwealth of Massachusetts

14. NEC 2003

15. NESC

16. IEEE

PART 2 – PRODUCTS

2.02 CONDUIT AND ACCESSORIES

F. Rigid Non-metallic Conduit

1. Fiberglass reinforced epoxy (FRE), UL approved. Exterior use.

2. Fittings shall conform to NEMA TC3.

3. Fiberglass Reinforced Thermo Resin Conduit (RTRC). Interior and Tunnel Use.

2.05 ASBESTOS CEMENT CONDUIT – Delete Paragraph

2.10 OUTLET, JUNCTION AND PULL BOXES

N. Provide identification labels on all junction and pull boxes. Labels shall be laminated plastic white with black core. Fasten with machine screws or rivets.

O. Provide a 1" air space gap between enclosures and walls in all locations. Utilize unistrut for mounting.

2.14 WIRE AND CABLE

A.4: Add the following paragraph:

d. No. 22 for telephones. Color code for individual conductors shall be green, black, yellow and red.

B. Add the following paragraph:

Flame retardency per IEEE 383 and low smoke per NFPA 258. Telephone cables shall be twisted pairs with gray polyethylene outer jacket; UL listed for Class 2 service.

NOTE: Applicable portions of Authority Specifications S-108B, S-114B, and S-118, which are included herein by reference and govern these Specifications.

E.1: Delete or pressure sensitive moisture-resistant.

J. Wire and cable 600 volts and below installed exposed in Tunnels.

1. Cable: UL labeled Type MC, suitable for wet and dry locations.

2. Jacket: Flame retardant and low smoke emission type, halogen-free thermoset jackets in accordance with the following requirements:

a. Passing flame test gas burner in accordance with IEEE 383.

b. Passing maximum smoke generation test in accordance with NFPA 258.

c. Insulated with ethylene-propylene-rubber and UL labeled type RHW.

3. Multiple Conductor Cables shall be as follows:

   a. Individual Conductors: Number as shown with the following additional requirements:

      1) Phase and neutral conductor insulated individually in accordance with requirements for single conductor cables or insulated with a composite compound of ethylene-propylene and polyethylene, UL, and UL labeled RHW or XHHW2.

      2) Neutral conductor of same size as that for phase conductor.

      3) Bare ground sized in accordance with NEC, unless shown otherwise.

   b. All conductors assembled with non-wicking, flame-resistant filler into circular configuration.

   c. Metallic Covering:

      1) Size No. 2 AWG and smaller conductor cable: Continuous aluminum sheath or interlocked tape armor in accordance with ICEA S-66-524, NEMA WC7.

      2) Size No. 1 AWG and larger conductor cable: Continuous aluminum sheath or interlocked aluminum tape armor in accordance with ICEA S-66-524, NEMA WC7.

2.19 WIREWAYS AND AUXILIARY GUTTERS

A. Construction: Shall be constructed from 16 gauge minimum steel. All straight lengths of wireways shall have hinged covers. Wireways shall be constructed with knockouts. Where shown on the drawings, field installable barriers shall be provided to separate the wireway into two or more separate compartments.

   Provide wire retainers for the wireway to hold cables and wires in place after installation. Wire retainers shall be designed so as to be installed or removed without the use of tools. Hangers shall be of two-piece construction and have provisions for either clamp, rod or bolted mounting applications. They shall permit preassembly of wireway and hanger bottom plates before hanging.

B. Finish: All sheet metal parts shall be provided with a corrosion resistant phosphatizing primer and ANSI 49 gray epoxy finish per ANSI Z55.1. All hardware shall be plated to prevent corrosion.

C. Listing: All wireway lengths and accessories shall be UL listed and labeled as prescribed in UL 870.

2.20 REMOTE CONTROL DEVICES

A. Push Button Stations: Oil tight type, heavy duty, in NEMA 12 enclosure, contacts, actuator and pilot lights as required, colored actuators and pilot light lens, rated 6 amps make and 6 amps break. Pilot lights and illuminated operators to have removable light modules and shall be convertible. Contact blocks to be double break, with captive screw terminals and silver contact

tips. Provide suitable legend plate for each operator. Furnish pushbuttons for emergency fans locking provisions.

B. Selector Switches: Similar to above with maintained contacts and actuator as required for the desired function. Switches to be HAND-OFF-AUTO unless otherwise noted.

2.21 IDENTIFICATION

A. Nameplates: Each piece of electrical equipment (including motor control center compartments) shall have a nameplate:

1. Nameplates shall be of three-ply plastic or lamicoid construction to produce a black letter on a white background.

2. Letters shall be 3/8 inch high arranged in two rows on large equipment, and 3/16 inch high on small individual items of equipment.

3. Nameplates shall be one inch high by three-inch wide.

4. Where equipment nomenclature requires additional space, nameplates shall be of such size to accommodate required nomenclature.

5. Nameplates shall be secured with two stainless steel screws.

6. Submit description of all nameplates to Engineer for approval before fabrication.

2.22 DIGITAL TRANSMISSION SYSTEM INTERFACE CABINET (DTSIC)

A. Cabinets shall conform with Article 373 of the National Electrical Code, with a gutter width of at least 4 inches on all sides, hinged cover and flush lock. Enclosures shall be gasketed and suitable for surface mounting. Terminal strips shall conform to Section 16920 with number of terminals as shown on Plans. Each terminal shall be clearly identified in accordance with wiring diagrams.

2.23 DIGITAL SIGNAL PROCESSOR

A. The Contractor is to furnish and install a Communication Programmable Logic Controller (CPLC) to provide digital transmission of indicator and control conditions to the 7th floor at 45 High Street and shall utilize the existing PCM Channel Banks leased lines or MBTA cables for remote transmission. The CPLC shall be fully compatible with the Authority's existing NVL-PLC and AVI Systems.. The contractor shall provide all hardware and software required for temporary and permanent operation of the CPLC System using a PCM channel on the newly installed channel bank. The CPLC shall be rack mounted in the Communication Room. The contractor shall provide, as a minimum, the following indications and controls:

1. Remote Motor Control - Transmitted / received to / from the 7th floor, 45 High Street for each vent fan control subsystem.

2. Fire Alarm Status and Trouble Condition - Transmitted to 45 High Street Control, 7th floor.

3. Security Alarm Condition - Transmitted to 45 High Street Control, 7th floor.

B. The full integration of all software and hardware elements into the existing co-processors such that local MCC, Fire Management Panel and all appropriate 45 High Street Consoles have full parallel control, shall be the sole responsibility of the Contractor. The task includes the integration of the FSK (Frequency Shift Keying) transmission sub-system associated with the FMPTS (Fire Management Panel Transmission System). The FMPTS System shall be provided under this contract.

C. The Contractor shall utilize the existing PCM Channel Banks for remote transmissions to 45 High Street. The Contractor shall be responsible for the interface between the Fire Alarm/Security alarm control panel, DTSIC, CPLC, 4th and 7th floor computers, and other designated terminals to be indicated by the Authority. Software data entry for indications and controls shall also be the responsibility of the Contractor.

D. Characteristics: PLC Processor shall be compatible with protocol of NVL-PLC and AVI System. The CPU shall have the capability of addressing up to 1024 input and output points. The system shall have a self-contained heater and battery back-up rated for 24 hours and power supply supplied from a 120 volt, 60 Hertz supply.

E. A minimum of 32K words (16-Bit) of internal, solid-state RAM memory shall be provided for storage of the control program. The full memory of the CPU shall be usable for program or data storage. The memory shall be expandable with the addition of RAM memory sub-modules.

F. Program back-up shall be on non-volatile EEPROM memory cartridges.

G. Program functions shall include contacts, coils, timers, counters, math functions (add, subtract, multiply, divide), shift registers, bit, and word operations.

H. The CPU shall include an integral real-time clock, backed up by internal lithium or long term type battery, which can be accessed from the control program. The clock shall include functions for time of day (year, month, day, hour, minute, second), alarm, and operation hours counter.

I. The CPU shall be capable of floating point math calculations including integer to floating point conversions, floating point to integer conversion, add, subtract, multiply, divide, square root and compare.

J. The CPU shall permit changing ladder program or data values while running.

K. Refer to Section 16741 of this Specification for detailed description and operation of the Communication Programmable Logic Controller.

2.24 FIRE MANAGEMENT TRANSMISSION SYSTEM (FMPTS)

A. General: Fully compatible with all control and indication functions of other Authority fire management panels, suitable for operation reliably and consistently in an electrically noisy transit environment for a distance of at least five miles using #19 twisted cable pair of a multi-pair cable.

B. Operation: System shall permit all control and indication functions from local fire management panel (FMP) to and from equipment in remote ventilation shaft, and shall be fully supervised, reporting any transmission failure to the digital signal processor (DSP) specified above for transmission of a trouble alarm. Initial system shall permit control of ventilation equipment as shown on the Contract Drawings.

C. Characteristics: System shall be a twelve channel, bi-directional frequency shift keying (FSK) encoder-decoder system, expandable with no external changes to 24 channels. Equipment shall be completely self-contained with all output isolation relays required, and with self-contained power supply suitable for operation on 120 volts, 60 Hertz.

D. A CPU within the Motor Control Center shall provide the interface to the Communication Programmable Logic Controller (CPLC) as specified in Section 16314.

2.26 TELEPHONE

A. Telephone, for locations other than wayside, shall be a standard heavy duty commercial unit for wall mounting, with handset, armored handset cord, bell ringer assembly, condensers, induction coil, 10 digit dial, handset switch, and other devices as required.

2.27 RUBBER MATS

A. Suitable rubber mats with canvas backs and beveled edges of the size required shall be provided on the floors of the switchgear and MCC rooms, both in front of and in rear of cubicles, panelboards or switchboards. The mats shall be ½ inch thick with corrugations running the long way of the mats and shall meet the requirements of the American Society of Testing and Materials. The matting in front or rear of any one switchboard or panelboard shall be in one piece and, when installed, shall be flat without curling.

2.28 SAFETY SWITCHES

A. Provide disconnect switches fused as shown on drawings. Switches shall be NEMA type HD safety switches for heavy duty use with interlocking cover, side operated. Switches exposed to weather shall have rain-tight enclosures. Switch enclosure shall be NEMA Listed for location and atmosphere in which they are mounted. Current carrying parts shall be silver plated. Disconnect switches shall be manufactured by General Electric, Square D, Siemens or Cutler-Hammer.

PART 3 – EXECUTION

3.02 CONDUIT AND FITTINGS

A. 24. Conduit Application

a. Rigid Galvanized Steel Conduit

1) Shall be used for all conduit runs, indoor and outdoor.

2) Embedded in floor or ceiling slab.

b. Intermediate Metal Conduit: Shall not be used.

c. Rigid Aluminum Conduit: Shall not be used.

d. Electrical Metallic Tubing (EMT): Shall be used:

1) For temporary use only.

e. Electrical Metallic Tubing shall not be installed anywhere:

1) Underground.

2) Encased in concrete.

3) In areas where subject to severe physical damage.

4) In hazardous areas.

5) Outdoors.

6) In locations and applications specifically prohibited by applicable codes.

7) Exposed conduit runs.

8) Damp locations.

f. Flexible Metal Conduit: Shall be used:

1) For connection to lighting fixtures where applicable.

2) For connection of equipment subject to vibration, noise transmission or movement.

g. Liquid-Tight Flexible Metal Conduit: Shall be used:

1) For flexible connection of short length to all motors.

2) For connection of short length to equipment located in the locations and subject to vibration, water, noise transmissions or movement, with a maximum length of 36".

h. Rigid Non-Metallic Conduit: Shall be used:

1) For installation in concrete structure.

2) For installation below ground floor slab.

3) For installation below grade.

Conduit(s) shall be encased in a minimum of three inches of concrete.

Conduit(s) shall be connected to rigid metallic "GRS" conduit before rising through floor slab.

E. Provide waterproof identification tags for all conduit runs and stubs.

3.07 UNDERFLOOR DUCTS AND FITTINGS – Delete Paragraph

3.10 FIELD TESTS AND INSPECTIONS

A. General: Provide all test equipment and personnel and submit written copies of all test results. Field tests and inspection shall be performed as specified in accordance with this section or other sections of Division 16 or in accordance with MBTA requirements.

B. Instruments used for measurements shall be accurate. Provide calibration histories for each instrument for examination. Calibration of each test instrument shall be by an approved laboratory or by the instrument manufacturer. The Engineer has the right to request instrument recalibration, or use of other instruments and test methodology where accuracy of readings if questionable. Instrument's application shall comply with the instrument manufacturer's certified instructions.

C. Wiring System Testing: Shall be performed as specified in Section 16120, "Wires and Cables."

D. Grounding Systems Tests: Shall be performed as specified in Section 16450, "Grounding."

E. Devices Subject to Manual Operation: Each device subject to manual operation shall be operated at least five times, demonstrating satisfactory operation each time.

3.11 TESTING

A. The Contractor shall conduct such tests and adjustments of equipment as necessary to verify performance requirements. Submit data taken during such tests to Owner's representative and testing agent. The Contractor shall megger test feeders, bus duct, branch circuit, and equipment, etc. for new and relocated equipment.

B. It is the responsibility of the Electrical Contractor to contact the MBTA upon completion of work in order to provide a final "In House" inspection and test.

C. Test and inspect all parts of work provided under this Section and as required by codes, standards, or authorities having jurisdiction. Conduct all tests and inspections to the complete satisfaction of all authorities and owners testing agent.

D. All systems shall test for short circuits and grounds, shall be free from mechanical and electrical defects, and shall show an insulation resistance between phase conductors and ground.

E. Test all circuits for proper neutral connections.

F. Failure or defects in workmanship or materials revealed by tests or inspection shall be corrected promptly and retested. Defective material shall be replaced at no additional expense to the Owner.

3.12 HYDRAULIC ELEVATOR COOORDINATION

A. The Electrical Contractor is responsible to obtain a copy of the "POWER SUPPLY – CONFIRMATION DATA FORM". See Section 14240 "HYDRAULIC ELEVATORS" ATTACHMENT A. The Electrical Contractor shall notify the Authority if the power supply is not coordinated with the contract drawings or specifications.

3.13 PHASING, DEMOLITION, SHUTDOWN, AND MAINTAINING EXISTING SERVICES

A. General

1. During the execution of the work, required relocation, rerouting, etc., of existing equipment and systems in the existing station where new work is to be installed or new connections are scheduled to be made, shall be performed by the Contractor as indicated on the drawings, and/or as required by job conditions and as determined by the Engineer in the field, to facilitate the installation of the new systems. The Owner will require continuous operation of all existing systems, while demolition, relocation work, or new tie-ins will be performed.

B. Shutdown

1. Outages required for construction purposes shall be scheduled for the shortest practical periods of time, in coordination with the Owner's designated representative, for specified, mutually agreeable period of time, after each of which the interruption shall cease and the service shall be restored. Any and all shutdowns which require the interruption of power of existing areas which must be on-line shall be scheduled during formal shutdowns such as "Holiday Shutdowns" or as designated by the MBTA This procedure shall be repeated to suit the Owner's working schedule as many times as required until all work is performed. Any shutdown of equipment will require a two week notice to owner.

2. Prior to any deactivation and relocation or demolition work, consult the drawings and arrange a conference with the Engineer and the Owner's representative in the field to inspect each of the items to be deactivated, removed or relocated. Care shall be taken to protect all equipment designed to be relocated and reused or to remain in operation and be integrated with the new systems.

3. All deactivation, relocation, and temporary tie-ins of electrical systems and equipment shall be provided by the Contractor.

4. Shutdowns requiring longer than 4 hours must be done on weekends, coordinate times with owners.

3.14 MISCELLANEOUS EQUIPMENT

A. Communication Programmable Logic Controllers (CPLC Units): Units shall be rack mounted where shown on Plans and provided with power supply wiring. Contractor is responsible for complete end-to-end wiring of the System.

B. Fire Management Transmission System: Units shall be wall mounted remote control panels, as shown on Drawings. Wiring units shall be complete including power supply and all connections to the motor control center and fire management panels. Testing of the complete system shall be as directed by the Engineer.

C. All wall mounted equipment shall be provided with non-metallic stand-offs.

3.15 MODIFICATION TO EXISTING WIRING

A. Existing wiring, lighting fixtures, boxes and electrical equipment interfering with the new construction shall be removed or replaced as required. Abandoned wiring shall be removed completely to the last device retained in service. Existing lighting fixtures being removed shall be replaced with new fixtures of types as shown. All modified and replaced work shall be left in first class condition and ready for normal operation.

B. All materials and workmanship shall conform with applicable sections of this specification.

3.16 OTHER ELECTRICAL WORK AT VENT SHAFT B5

A. At the tunnel level of Vent Shaft B5 replace corroded electrical conduit, wiring and associated items at the direction of the Engineer. This work will be done on a time and materials basis under the allowance item No. 1600.358, Other Electrical Work

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. The Work specified in this Section will be measured and paid for under the various Sections specified involving their use.

B. No separate measurement nor payment will be made for electrical work required for the tunnel emergency ventilation system but all cost shall be included in pay item TUNNEL VENTILATION SYSTEMS on a lump sum basis furnished and installed complete in place as shown on the Contract Drawings, including all demolition, temporary construction and staging of demolition, modifications to existing switchgear, primary cable, all remote control devices, junction boxes, communication junction boxes and related communication and supervisory control cables, modifications to existing wiring, interim electrical systems, CPLC Systems, fire management transmission systems, fire retardant barriers, sealing, caulking, patching, system and equipment grounding, and all other equipment and wiring as required for completely operational systems and removal of abandoned conduit, wiring, boxes and devices as required for a completely operational systems as shown on the Contract Drawings and as specified herein.

C. An allowance sum as specified in Section 01020 shall be included in the Bid for OTHER ELECTRICAL WORK to replace corroded conduit and wiring located at the Tunnel Level at

Vent Shaft B5. See Item No. 1600.358 in the bid form. The Contractor shall submit approved time slips and signed receipts to the Engineer for review and approval.

D. No separate measurement or payment will be made for electrical work required for RACEWAY SYSTEMS but all cost shall be included in Payment Item WIRE, CABLE, CONDUIT No. 1610.105 on a lump sum basis, furnished and installed complete in place as shown on the Contract Drawings. Raceway Systems shall include all surface mounted and embedded conduits, troughs, wiremold, cable tray, etc. with all fittings, junction boxes, terminations and hangers. Raceway Systems shall be empty. See Section 16120 for wires and cables.

4.02 PAYMENT ITEMS

ITEM NO.	DESCRIPTION	UNIT
1586.040	TUNNEL VENTILATION SYSTEM	LS
1600.358	OTHER ELECTRICAL WORK	AL

END OF SECTION

SECTION 16070

ELECTRICAL - MECHANICAL INTERFACE

PART 1 – GENERAL

1.01 SCOPE

A. The Scope of Work under this Section, without limiting the generality thereof, includes the furnishing and coordination of all labor, materials, equipment, services, and incidentals necessary to complete all mechanical and electrical work in accordance with the intent of the Specifications and the Drawings. All systems shall be complete, tested and fully operational prior to the acceptance of same by the Owner.

B. The Work shall consist of but not necessarily be limited to the following:

1. Power wiring for plumbing, HVAC, and tunnel ventilation systems equipment.

2. Interlock (line voltage) wiring required for the operation of mechanical equipment furnished and installed under the HVAC and Plumbing Sections of the Specifications. Automatic Temperature Control wiring is not considered a part of interlock wiring and will be provided under Section 15600.

3. Safety switches.

4. Coordination with all Authorities Having Jurisdiction and other trade contractors.

1.02 SUBMITTALS

A. Submittals shall be in accordance with Section 01300, except as modified herein.

B. Submit coordination drawings and schedules prior to submitting shop drawings, and supplemental data.

C. Submit equipment delivery, installation and removal plan.

D. Coordination of Shop Drawings and Supplemental Data

1. Prior to submittal, review for compliance with the Contract Documents.

   a. Check field dimensions and clearance dimensions.
   b. Check relation to available space.
   c. Check anchor bolt settings.
   d. Review the effect of any changes on the work of other trades.
   e. Review the effect of any changes on work of other Sections.
   f. Check compatibility with equipment and work of other Sections.
   g. Check electrical characteristics and operational control requirements.
   h. Check actual motor nameplate voltages and control characteristics against the Contract Documents.
   i. Coordinate controls and interlocks:
      1) Voltages
      2) Wiring of electrical switches or relays.
   j. Coordinate wiring and control diagrams.

k. Check for interference/accessibility to equipment problems, obstructions, and interferences with items, including, but not limited to, access panels, and doors that could hinder or prevent work including, but not limited to maintenance, and disassembly.

1.03 MECHANICAL AND ELECTRICAL WORK COORDINATION

A. Coordinate the work of Divisions 2, 3, 5, 8, 13, 14, 15, and 16 and the work of other Divisions as related to mechanical and electrical work.

B. Coordinate progress schedules, including dates for submittals and for delivery of products/materials/equipment.

C. Conduct conferences among mechanical and electrical trades, and other concerned parties/trades, as necessary, to maintain coordination and schedules, and to resolve coordination matters in dispute.

D. Report progress of mechanical and electrical work at project meetings.

E. Verify that utilities, connections, and controls are complete and that equipment is in operable condition prior to energization/activation/testing.

F. Report on interference/accessibility to equipment problems, obstructions, and interferences with items including, but not limited to, access panels, and doors that could hinder or prevent work including, but not limited to maintenance, and disassembly.

1.04 COORDINATION DOCUMENTS

A. Prepare coordination drawings to organize the layout and installation of products/material/equipment for efficient use of available space, for proper sequence of installation and to identify potential conflicts.

1. Scale of coordination drawings, sections, elevations, and details shall be as required by the Engineer.

2. Show actual sizes of equipment, ducts, conduit, and piping. Label all elements of the system with most definitive nomenclature, name and model.

3. Show all applicable systems on drawings.

4. Locate, by dimension, system elements in relation to fixed architectural/structural work such as heights above slabs, and from wall faces.

5. Submit coordination drawings to the Engineer for review and approval.

6. Reproduce and distribute reviewed and approved coordination drawings to all concerned parties.

B. Furnish to trades advance information on locations and size of items including, but not limited to, frames, boxes, sleeves, and openings needed for their work, and also furnish information and shop drawings necessary to permit trades affected by the work to install same property and without delay.

C. If any mechanical and/or electrical work has been installed before coordination with other trades so as to cause interference with the work of such trades, all necessary adjustments and corrections shall be made by the mechanical and/or electrical trades involved at no additional cost to the Authority.

D. Identify, in advance, electrical power characteristics and control wiring required for each item of equipment.

1.05 CODES, ORDINANCES AND REGULATIONS

A. The installation and material furnished shall comply with the regulations of the National Electrical Code, State and Local Building Department Codes, and all legally constituted authorities having jurisdiction. Where the drawings and/or Specification requirements exceed the requirements of the applicable codes the requirements specified in the Contract Documents shall take precedence.

1.06 HANDLING OF MATERIALS

A. Receive and accept at the site, properly handle, house and protect from injury as well as the weather until ready for installation, the following materials.

1. Materials, equipment and apparatus furnished under this Section.

2. Electrical control equipment furnished under other Sections of the Specifications and to be installed under this Section.

B. Equipment damaged in the course of handling, installation or test shall be replaced under this Section or repaired to the satisfaction of the Engineer without any additional charge.

C. Trailers for storage of electrical materials and equipment, if required, by the General Contractor, shall be provided under this Section. Trailers shall be located in designated staging areas at the site.

1.07 PROTECTION

A. It shall be the responsibility of the Contractor for the maintenance and protection of all materials and equipment provided during all phases of construction from loss damage or deterioration until final acceptance by the Engineer.

1.08 OPERATING AND MAINTENANCE INSTRUCTIONS

A. Prior to completion of the Contract, provide operating instructions to the Owner's designated representative with respect to operation functions and maintenance procedures for all equipment and systems installed. Thoroughly instruct the Owner's representatives in the operation of all electrical systems and components to the complete satisfaction of the Owner. Advise the Owner's representatives as to the location of all electrical equipment associated with the various systems.

PART 2 - PRODUCTS

2.01 GENERAL

A. Materials and equipment included under this Part and required for the proper installation and operation of the electrical system shall comply with the applicable requirements of Part 1 of this Section.

PART 3 – EXECUTION

(Not used)

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. The work and items specified under this Section will be measured and paid for under the various sections specified involving their use.

END OF SECTION

SECTION 16120

WIRES AND CABLES

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies work that consists of furnishing, installing and testing of wires, cables, splices, terminations and associated accessories.

B. The General Documents, as listed on the Table of Contents and applicable parts of Division 1, General Requirements, and requirements of Section 16050, shall be included in and made part of this Section.

1.02 APPLICABLE PUBLICATIONS

A. The publications listed below form a part of these Specifications to the extent referenced. The publications are referred to in the text by basic designation only. In case of conflict between provisions of codes, laws, ordinances, and these Specifications, including the Contract Drawings, the more stringent requirements will apply.

1. National Fire Protection Association (NFPA) Publication:

   70.02 - National Electrical Code

2. American Society for Testing and Materials (ASTM) Publications:

   B1 - Hard-Drawn Copper Wire

   B2 - Medium-Hard-Drawn Copper Wire

   B3 - Soft or Annealed Copper Wire

   B8 - Concentric-Lay-Stranded Copper Conductor

   B33 - Tinned Soft or Annealed Copper Wire for Electrical Purposes

   B174 - Bunch-Stranded Copper Conductors for Electrical Purposes

   D1373 - Medium-Voltage Rubber Insulating Tape

   D3005 - Low-Temperature Resistant Vinyl Chloride Plastic Pressure-Sensitive Electrical Insulating Tape

3. American National Standards Institute/Underwriter's Laboratories Inc. (ANSI/UL) Publications:

44 - Rubber-Insulated Wire and Cable

62 - Flexible Cord and Fixture Wire

510 - Insulating Tape

4. Underwriter's Laboratories Inc. (UL) Publications:

1581 - Reference Standard for Electrical Wires, Cables, and Flexible Cords

486A - Wire Connectors and Soldering Lugs for Use with Copper Conductors

5. Insulated Cable Engineers Association/National Electrical Manufacturer's Association (ICEA/NEMA) Publications:

S–68–516/WC8 Ethylene-Propylene-Rubber Insulated Wire and Cable for the Transmission of Electrical Energy

6. Institute of Electrical and Electronic Engineers, Inc. (IEEE) Publications:

48 - Standard Test Procedures and Requirements for High-Voltage Alternating Current Cable Terminators

404 - Standard for Power Cable Joints

383 - Class 1E Electrical Cables, Field Splices and Connections

7. Association of Edison Illuminating Companies (AEIC) Publications:

1 - Specifications for Impregnated Paper Insulated Lead Covered Cable, Solid Type (Latest Edition)

CS8 - Specification for Ethylene Propylene Rubber Insulated Shielded Power Cables Rated 5 through 69 kV

8. American National Standards Institute (ANSI) Publication:

C2 - National Electrical Safety Code

9. Board of Fire Prevention Regulations:

527 CMR 12.00 Massachusetts Electrical Code

10. MBTA 1000 Volt DC wire, specifications MBTA P-30C.

11. MBTA 15 KV Cable, MBTA Specification P-73.

12. 1,000 MCM Cable, MBTA Specification P - 118C and P- 119C.

1.03 SUBMITTALS

A. Manufacturer's Data: Shall be submitted for the following:

1. TC-Type cable in cable trays for power system and equipment SCADA systems.
2. 600 Volt Rated Wires and Cables
3. 15 KV Cable
4. SIS-Type cable in switchgear for control power and SCADA system, etc.
5. Cable Pulling Lubricants
6. Insulating Tapes
7. Terminators
8. Splice Kits
9. Mineral Insulated Metal Sheath Cable (MI)
10. Type MC Fire Rated Cable

B. Manufacturer's Instructions:

1. Manufacturer's directions for use of ground megger with proposed method indicated.
2. Typical installation instructions for splicing and terminating kits.

C. Test Reports: Shall be submitted for the following:

1. 600 Volt Rated Wires and Cables
2. 15 KV Rated Cable

1.04 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Mark each single-conductor cable and each multi-conductor cable to show UL label, size, voltage rating, manufacturer and number of conductors where applicable.

B. Ship each component or unit securely packaged and labeled for safe handling in shipment and to avoid damage.

C. Store materials in secure and dry facility and in original packaging in a manner to prevent soiling, physical damage, wetting or corrosion prior to installation.

PART 2 - PRODUCTS

2.01 GENERAL

A. All materials, equipment, and devices shall, as a minimum, meet the requirements of UL, where UL standards are established for those items, and the requirements of NFPA 70. All equipment and materials provided shall be new, unless specified otherwise or indicated.

B. Wire and cable conductor sizes are designated by American Wire Gauge (AWG) and Thousands of Circular Mils (kcmil)

2.02 600 VOLT RATED WIRES AND CABLES:

A. General:

1. Wires and cables shall meet the applicable requirements of NFPA 70 and UL for the type of insulation, jacket and conductor specified or indicated.

2. Wires and cables manufactured more than 12 months prior to date of delivery to the site shall not be used.

3. The Contract Drawings show the location, size and number of wires and cables to be provided under this contract.

B. General - Purpose Wires and Cables:

1. Application: For power and branch circuit wiring, installed in conduit and/or wireway.

2. Conductors: Solid per ASTM B3, or annealed copper Class B stranded per ASTM B8. Conductors No. 10 AWG and smaller shall be solid; those No. 8 AWG and larger shall be stranded. All conductors shall be copper.

3. Insulation: Cross-Linked-Polyethylene

4. Type: NEC/UL Type XHHW or THWN

5. Minimum Conductor Size: No. 12 AWG

6. Standards: ANSI/UL 44

7. Color Coding: Provide for feeder and branch circuit wiring as follows:

Conductor	System	Voltage
	208Y/120V	480Y/277V

Phase A	Black	Brown
Phase B	Red	Orange
Phase C	Blue	Yellow
Neutral	White	Gray
Ground	Green	Green

C. Special - Purpose Wires and Cables:

1. Application: For power, control and branch circuit wiring in tunnels and where specifically shown on the Contract Drawings, installed in conduits.

2. Conductors: Solid per ASTM B3, or annealed copper Class B stranded per ASTM B8, ICEA S-68-516/NEMA WC8, ANSI/UL 44 and UL 1581. Conductors No. 10 AWG and smaller shall be solid and those No.8 AWG and larger shall be stranded for power and branch circuit wiring. Conductors for control and signal wiring shall all be stranded. All conductors shall be copper.

3. Insulation: Heat, moisture and chemical resistant ethylene-propylene co-vulcanizate compound (EPCV) categorized by UL as Class XL, Type XHHW, rated VW-1, meeting or exceeding all electrical, aging and physical requirements of ANSI/UL 44 and ICEA S-68-516/NEMA WC8.

4. Type: NEC/UL XHHW.

5. Minimum Conductor Size: Minimum size for power and branch circuit wiring shall be No. 12 AWG, minimum size for control and signal wiring shall be No. 14 AWG.

6. Flammability Requirements: Shall meet the requirements of UL 1581 Vertical Wire Flame Test for VW-1 rating.

D. Lighting Fixture Wire:

1. Type: NEC/UL Type SF-2

2. Insulation: Silicon rubber

3. Conductors: Stranded

4. Standards: ANSI/UL 62.

E. Single Conductor Control Cable and Wire:

1. Application: For control and signal circuit wiring, installed in conduit and/or wireway.

2. Conductors: Class B stranded per ASTM B8.

3. Insulation: Cross-linked polyethylene.

4. Type: NEC/UL XHHW

5. Standards: ANSI/UL 44.

2.03 15 KV RATED CABLE

A. The 15 kV power cable shall be constructed of EPR insulation. Conductors shall be stranded copper. Insulation Level shall be 133%, 90^0C Conductor temperature insulation rating. Cables shall be shielded single conductor. Jacket shall be XLPE or PE. See Appendix for MBTA Cable specifications.

2.04 GROUNDING CONDUCTORS

A. Grounding Electrode Conductors:

1. Insulated: No. 6 AWG and smaller shall be solid copper per ASTM B3, those No. 4 AWG and larger shall be copper Class B stranded per ASTM B8. Type shall be same as power conductors.

2. Uninsulated:

   a. No. 6 AWG and smaller shall be solid copper per ASTM B3, those No. 4 AWG and larger shall be copper, Class B stranded per ASTM B8.

   b. Direct Buried or Encased in Concrete: Soft-drawn; medium-hard drawn; or hard-drawn conforming to ASTM B1, B2, or B3 respectively.

B. Equipment Grounding Conductors:

1. Insulated: No. 10 AWG and smaller shall be solid copper per ASTM B3, those No. 8 AWG and larger shall be copper, Class B stranded per ASTM B8. Type shall be the same as power or branch circuit conductors. Covering shall be continuous green color.

2. Uninsulated: No. 10 AWG and smaller shall be solid bare copper per ASTM B3, those No. 8 AWG and larger shall be copper, Class B stranded per ASTM B8.

2.05 BONDING CONDUCTORS

A. No. 8 AWG and smaller shall be solid bare copper conforming to ASTM B1; those No. 6 AWG and larger shall be Class B stranded bare copper conforming to ASTM B8.

2.07 WIRE AND CABLE INSTALLED EXPOSED IN TUNNEL

A. FMPTS cable: 2 pair #19, twisted shielded with low smoke jacket, per Authority Specification S108A and S114B.

B. Communication cable: 4 pair #19, and 25 pair #19 twisted shielded with low smoke jacket, per Authority specification S108A and S114B.

C. Telephone cable: 4 conductor, twisted shielded with low smoke jacket, per Authority specification S108A and S114B.

2.08 SPLICING AND TERMINATION MATERIALS FOR 600 VOLT RATED WIRE AND CABLES

A. Connectors: Meeting the requirements of UL 486A.

1. No. 10 AWG Conductors and Smaller: Insulated, pressure-type connectors (twist lock), rated 600 volts, 105 degrees Centigrade.

2. No. 8 AWG to No. 4/0 AWG Conductors: Tin-plated copper compression type connectors.

3. 250 kcmil Conductors and Larger: Long-barrel tin-plated copper double-compression type connectors.

B. Terminals: Meeting the requirements of UL 486A

1. No. 8 AWG Stranded Conductors and Smaller: Insulated or uninsulated compression type ring-tongue terminals.

2. No. 6 AWG to No. 4/0 AWG Conductors: NEMA 2-hole, tin plated copper compression type terminals.

3. 250 kcmil Conductors and Larger: NEMA 2-hole, tin plated copper, long barrel, double-compression type terminals.

C. Tapes:

1. Vinyl Tape: Conforming to ANSI/UL 510 and ASTM D3005.

a. Interior and Dry Locations: 7 mils, ASTM D3005 (Type 1), Scotch (3M) No. 33, or accepted equal.

b. Exterior or Damp and Wet Locations: 8.5 mils, ASTM D3005 (Type II), Scotch (3M) No. 88, or accepted equal.

2. Rubber Tape: 30 mils thick, ethylene propylene rubber (EPR) based, rated for 130 degrees Centigrade operation, conforming to ASTM D1373, Scotch (3M) No. 130C, or accepted equal.

PART 3 - EXECUTION

3.01 INSTALLATION OF WIRES AND CABLES RATED 600 VOLT AND BELOW

A. General: Installation shall conform to the requirements of NFPA 70, Massachusetts Electrical Code and to the requirements specified herein.

B. Minimum Conductor Sizes: No. 12 AWG for power and branch circuit wiring, No. 14 AWG for control and signal wiring, except where shown otherwise on the Contract Drawings.

C. Conductor Identification:

1. All wires and cables shall be identified by circuit numbers in all cabinets, boxes, manholes, wireways and other enclosures and access locations and at all terminal points.

2. Circuit designations shall be as shown on the Contract Drawings.

3. The tag ties shall be wrapped around all conductors comprising the circuit or feeder to be identified.

4. Cable Tags:

a. Dry Locations: Fiber Tags, 1/16 inch thick and 3/4 inch wide, indented with letters and numbers approximately 5/16 inch high, fastened to cables with nylon cable ties. Lighting branch circuit wiring and single conductor signal and control wiring may be identified by "Quicklabels" manufactured by W. H. Brady Company or engineer approved equal.

b. Wet Locations: Stainless steel metal tags, No. 28 gauge and 3/4-inch wide, embossed with letters and numbers approximately 5/16 inch high, fastened to the cable or wire with nylon cable ties.

D. Splices and Terminations:

1. General: Splices and terminations shall be made in outlet, junction or pull boxes in wireways or in equipment cabinets and shall be made mechanically and electrically secure, using proper splicing and termination equipment and components as specified herein.

2. Splices - Dry Locations: No. 10 AWG conductors and smaller:

a. Shall be made with insulated pressure type connectors over which there shall be applied two half layers of vinyl tape extending approximately 3/4 inch from the connector.

3. Splices - Dry Locations: No. 8 AWG conductors and larger:

   a. Shall be made with compression type connector and splicing tape applied to equal the original insulation rating, or a shrinkable type tubing installed.

4. Splices - Wet Locations:

   a. Same as Dry Locations above, except after tape is applied, cover with two coats of sealer.

5. Splices and Terminations - Dry Locations: No. 8 AWG stranded conductors and smaller:

   a. Shall be made with insulated or uninsulated compression type ring-tongue terminals.

6. Terminations - Dry Locations: No. 6 AWG to No. 4/0 AWG conductors:

   a. Shall be made with NEMA 2-hole compression type terminals.

7. Terminations - Dry Locations: 250 kcmil conductors and larger:

   a. Shall be made with NEMA 2-hole, long barrel, double compression type terminals.

8. Terminations - Wet Locations:

   a. Once the termination has been completed in accordance with the requirements of the paragraphs "Terminations - Dry Locations", cover the entire termination area with two half-lapped layers of vinyl tape and apply two coats of sealer over the tape.

9. Terminations/Splicing - Control Cables:

   a. Terminal strips shall be used for all terminations, interconnection and/or splicing of control cables or communication cables. These terminal strips shall be of the proper voltage, size and type, properly labeled and mounted in terminal strip boxes, outlet boxes or equipment cabinets.

10. Terminations/Splicing-Shielded Cables:

    a. Terminal strips shall be used for all terminations, interconnection and/or splicing of shielded control and instrumentation wires and cables. Where splice is made, the shield shall be continued through the splice. Shields shall be grounded at one location only, unless otherwise shown on the Contract Drawings or required by the equipment manufacturer.

3.02 INSTALLATION OF WIRES AND CABLES RATED 15 kV

A. Install cable in accordance with Manufacturer's instructions and IEEE C2.

B. When cable is cut, unless splicing is to be done immediately, seal the ends. Cable ends which have been exposed to the weather shall be cut back a minimum of one foot and sealed.

C. Arrange and permanently rack cables prior to splicing or terminating. Install duct shield of split nylon tube or equal to protect the cables at duct mouths. In manholes cable ends shall be above water level. All bending and racking shall be done in such a manner that cables will not bind at the duct mouth when splicing is completed. After bending, cable sheath shall be smooth and free from cracks and wrinkles. Where cables are racked in manholes, they shall rest on saddles with freedom of horizontal movement to accommodate such changes in length. Rack cables on both sides of manholes to allow for splicing.

D. Splicing and terminating of medium voltage cables shall be performed by qualified cable personnel only with experience on the types of cables installed. Prior to making any splice or termination the Contractor shall submit to the Engineer for approval the name of individuals who will perform this work, including experience on similar projects. All taps and splices shall be made within manholes or handholes unless specifically noted.

E. Conductor ends shall not be strand-snipped to reduce in size, nor shimmed to fit oversize splices. Splices shall be sized as required to fit the installed conductors.

F. Install fire protection tape, half-lapped on all 15 KV cable after other cable and splice work is completed. Asbestos cement mortars are not permitted.

G. Provide arc-proofing tape on all medium voltage cables in manholes and handholes.

3.03 FIELD TESTS AND INSPECTIONS

A. General: The Contractor shall provide all test equipment and personnel required for the performance of all field tests and inspections specified hereinafter.

B. 600 Volt Rated Wires and Cables:

1. Inspections:

a. Inspect cables for physical damage and proper connection in accordance with accepted shop drawings.

b. Test cable connections for proper torque in accordance with manufacturer's recommended values.

2. Tests:

a. After wiring is completed and connected ready for operation, but prior to placing in service and before any branch circuit breakers are closed, perform the following:

1) Continuity tests to insure proper cable connections.

2) Insulation resistance tests between conductors and between each conductor and ground.

Each coil, reel, or length of wire or cable shall have an insulation resistance of 60 degrees Fahrenheit (15.6 degrees Celsius) if not less than the value of "R" calculated by using the formula $R=k\log^{10} D/d$ as per ICEA.

Use an instrument capable of making measurements at an applied potential of 500 volts. Take readings after the voltage has been applied for a minimum of one (1) minute.

The readings shall be not less than:

Conductor or Circuit Size	Minimum Resistance
No. 14 and 12 AWG	1,000,000 ohms
25 ampere circuits and above	250,000 ohms

C. 15 KV (Medium voltage) Cable

1. Refer to MBTA/E & M, cable specifications.

2. Perform tests after installation, but prior to being energized when all splices have been completed but with all cable end sealed, except cable under test. Do not connect cables under test to equipment that might be damaged by test.

3. Conduct a non-destructive, direct current, dielectric test of insulation in accordance with the appropriate ICEA Standard.

4. Test cables at 80% of manufacturer's factory DC acceptance test voltage unless existing used cables are spliced into the circuit. When existing used cables are spliced into the circuit, cables shall be tested at 50% of the manufacturer's factory DC test voltage.

5. Cable in the same conduit, not under test, shall be properly grounded and connected to the shield of the cable under test. If it is necessary to repeat a test, or if the cable has been energized prior to testing, the capacitance and absorption current shall be completely drained by grounding conductors.

6. Perform a step-voltage test. Allow sufficient time for stabilization of the capacitance and absorption currents.

7. Correct all faults and retest the work as often as necessary to assure that all cables test out properly.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. No separate measurement shall be made for the Work of this Section.

4.02 PAYMENT

A. Payment will be at the contract lump sum price for the item listed below.

B. Measurement and Payment for Pay Item WIRE, CABLE, CONDUIT shall include wires, cables, splices, terminations and associated wire and cable accessories and conduit. See Section 16050 for description of materials and application.

4.03 PAYMENT ITEM

Item No.	Item Description	Unit
1610.105	WIRE, CABLE, CONDUIT	LS

END OF SECTION

SECTION 16123

CATENARY SYSTEM MODIFICATIONS

PART 1 - GENERAL

1.01 DESCRIPTION

A. The Contractor shall provide all labor, materials, construction equipment and services necessary for the relocation of the existing section insulator on the inbound track as shown on the Contract Drawings and as specified herein.

B. The Contractor shall relocate the existing pantograph detection system at Maverick Station as shown on the Contract Drawings. The pantograph detection system components referenced in this section are as follows: control and interface cases; 600 Vdc loop contactors; and, 600 Vdc positive and negative control power and indication circuits and associated hardware. Signal system components located on the signal system side of the pantograph detection interface case are specified elsewhere.

C. The work consists of the following:

1. Relocation of the existing section insulator on the inbound side of Maverick Station as shown on the Contract Drawings.

2. Relocation of the existing pantograph detection system on the inbound side of Maverick Station as shown on the Contract Drawings.

1.02 SUBMITTALS

A. The following information shall be submitted in accordance with Section 01300.

1. Pantograph Detection System Components

a. Prior to the relocation of pantograph detection system equipment, the Contractor shall submit the following for review and approval:

i. Layout plan of the system indicating the location and mounting methods of all major elements, including the loop contactors, junction boxes, conduit, detection cabinet, signal interface cabinet and disconnect switch.

ii. Catalog cuts, shop drawings, and other descriptive information for all new materials, include conduit and cabling. Submittal shall include manufacturer's recommended installation instructions where applicable..

b. Prior to start-up, the Contractor shall submit an approved Field Test Procedure for testing of the relocated pantograph detection system.

1.03 QUALITY ASSURANCE

A. General: Examine the conditions under which the components of the detection system are to be installed.

B. Notify the Engineer of conditions encountered or foreseen which could affect the installation of the detection system.

1.04 REFERENCES

A. Codes and Standards

1. Standards applicable to the detection system installation that have been listed in other sections of this Specification also apply here.

2. Comply with the most current provisions of the following, except as otherwise indicated. If there is a conflict between specifications and standards or between the various standards, then the most stringent requirement shall apply.

   a. American National Standards Institute (ANSI)

   b. National Electrical Safety Code (NESC)

   c. Occupational Safety and Health Act of 1970 (OSHA)

   d. National Electrical Manufacturers' Association (NEMA)

   e. Rules and regulations of the MBTA for performing work on MBTA property.

PART 2 - PRODUCTS

2.01 GENERAL REQUIREMENTS

A. Items shall be furnished that are of the materials, design, sizes and ratings shown on the Contract Drawings and specified herein.

B. Pantograph Detection System

1. All electrical conductors shall meet MBTA Specification S-114-B, Specification for Low Smoke, No Halogen Signal Wire and Cable, included as a Technical Appendix to these specifications. Electrical conductors are specified in Section 16808, External Signal Cable.

2. All raceways for the electrical conductors shall meet MBTA Specification P-180A, Specification for Fiberglass Reinforced Conduit, Interior Use, Extra Heavy Wall, included as Technical Appendix A. Raceways for electrical conductors are specified in Section 16877, Miscellaneous Components & Products.

3. Equipment types, sizes and electrical ratings shall be as shown on the Contract Drawings.

PART 3 - EXECUTION

3.01 EQUIPMENT AND HARDWARE INSTALLATION AND TRANSFER

A. The Contractor shall submit to the Engineer, in writing, a request with the proposed schedule including dates, times, and the methods to be used. Coordination will be required with the Authority to agree on a date and time for each site and the action of work required by each party.

3.02 OTHER SUPPORT SYSTEMS AND FITTINGS

A. Relocated fittings and support systems shall be installed at other designated locations, such as power section breaks, as shown on the Contract Drawings.

B. Existing hardware attached to the existing trolley wire, such as pantograph sensors and switch heater taps, shall be removed as indicated on the Contract Drawings. Reinstallation of hardware in relocated position will be supervised by the Engineer.

PART 4 - MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. The relocation of the existing pantograph detection system, including relocation of the existing section insulator, as specified in this section shall be measured in place furnished, installed and tested.

4.02 PAYMENT

A. Payment will be paid on a lump sum basis. Such price and payment shall represent full compensation for completing the work including all labor, materials, equipment and incidentals necessary to complete the work ass shown on the Contract Drawings and specified herein.

1696.011	Remove, Protect, Reinstall and Test, Signal and Traction Power System	LS

END OF SECTION

SECTION 16125

DC POWER CABLE AND DC POWER FEEDER DISCONNECT SWITCH

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies removing, terminating, existing 1,000,000 circular mil ethylene propylene rubber (EPR) insulated, cross-linked polyolefin (XLPO) jacketed cable for 650 Volt dc positive feeders, and third rail jumpers.

B. This Section specifies the replacement of manual dc traction power disconnect switch BJ/968 as shown on Contract Drawings and described herein.

C. This Section specifies the installation of new cable tags and cable terminations.

1.02 SUBMITTALS

A. Submit the following for the dc traction disconnect switches in accordance with section 01300.

1. Detail drawings of the disconnect switch and enclosure, including composite of switch in the enclosure.

2. Bill of material

PART 2 - PRODUCTS

2.01 DC TRACTION FEEDER POSITIVE CABLE

A. No new cable will be required.

2.02 TRACTION POWER DISCONNECT SWITCH

A. Furnish new traction power 2000A. disconnect switch and enclosures in accordance with MBTA Specification P-150C dated May 1996, included as an appendix to these specification.

B. Replace the existing wayside switches as specified herein and as shown on the Contract Drawings.

PART 3 - EXECUTION

3.01 INSTALLATION

A. The existing cables to the new switch BJ/968 can be utilized to feed to and from the new switch location. The cables will be removed from the existing switch so the new switch can be installed.

The following procedure is hereby established in removing the existing cables.

a. MBTA will de-energize the cables to be removed.

b. Contractor will remove the cables from switchbox when the pit third rail is de-energized. The cables ends will then be insulated since the other end of the cables are still connected to the third rail which will become energized by closing switch J/949.at the entering end of the pit rail.

B. Install split nylon tube type duct shields to protect the cable at the wall penetration.

C. The minimum bending radii employed shall not be less than those recommended by manufacturers or not less than 8 times the outside diameter of the cable, whichever is larger.

D. Install new cable supports to enable a neat arrangement of the cables at disconnect switch. The cables are to be supported by fiberglass clamps mounted on unistrut channel secured to the wall with 1/2"expansion bolt.

E. Install new Traction Power Disconnect Switch BJ/968.

1. Remove existing disconnect switch BJ/968 and turn it over to the MBTA's Transmission and Distribution Division.

2. Install new traction power disconnect switch BJ/968 and enclosure. Install new cable clamp supports as specified in Section 3.01 paragraph D.

3. Install switch enclosure plumb and level and in alignment with adjoining work or structure in accordance with the Contract Drawings. In addition install new fiberglass cable enclosure as shown on the Contract Drawings.

F. After switch box installation, cut back the four 1000 kcmil cables from manhole 1912 and terminate the cables on the switch.

G. Mark cables using printed numbers on cable tags in the switchbox and beneath the switchbox. Standard MBTA cable tags shall be used i.e. Cable identification tags shall be fabricated from polyethylene with black 1" high characters on yellow background.

3.02 FIELD TESTING

A. None required, since the cables were live-capped.

PART 4 – MEASUREMENT AND PAYMENT

4.01 METHOD OF MEASUREMENT

A. Separate Measurement will not be made for removing, terminating, cable, cable tags and miscellaneous materials specified in this Section.

B. Separate Measurement will not be made for removing wayside disconnect switch and enclosure nor for the installation of new wayside switch BJ/968, enclosure, and fiberglass cable enclosure.

4.02 BASIS OF PAYMENT

A. All cost associated for installing cable tags and miscellaneous materials specified in this Section will be included into Pay Item 1630.210 DC Electrification. All cost in connection therewith will be considered incidental to this item of work to which they pertain.

B. All cost associated for removing wayside disconnect switch and enclosure, installing new disconnect switch and enclosure and cable enclosure specified in this section will be included under Pay Item 1630.210 DC Electrification. All cost in connection therewith will be considered incidental to this item or items of work to which they pertain.

C. All cost associated for removal of DC cables (shorting existing cables) required under this Section will be included under Pay Item 1630.210. All cost in connection therewith will be considered incidental to this item or items of work to which they pertain.

4.03 PAYMENT ITEM

ITEM NO.	PAYMENT ITEM	UNIT
1630.210	DC Electrification	LS

END OF SECTION

SECTION 16153

CONSTRUCTION OF UNDERGROUND CONDUIT DUCT BANKS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies Work that consists of providing all labor, materials, construction equipment and services necessary for constructing the reinforced concrete encased duct banks. The size, configuration, construction features, approximate location of duct banks required shall be as shown on the drawings.

B. The General Documents, as listed on the Table of Contents and applicable parts of Division 1, General Requirements, and requirements of Section 16050, shall be included in and made part of this Section.

1.02 PERMITS AND LICENSES

A. The Contractor is responsible for obtaining the required permits and licenses for performing the actual work. The Contractor shall not prosecute any work in the streets prior to the City granting the license. The Contract price is deemed to be inclusive of all expenses including prescribed fees and any other pertinent costs associated in obtaining these permits and licenses.

1.03 SAFETY FEATURES

A. Contractor shall conform to all Federal, Sate, and Local rules and regulations including, but not be limited to, Bulletin No. 12 - Rules and Regulations for Prevention of Accidents in Construction Operations published by the Commonwealth of Massachusetts.

PART 2 - PRODUCTS

2.01 ORDINARY BACKFILL

A. The material removed in excavation may be used for common backfill provided it is clean and free from refuse, debris, organic material, stumps, frozen material, large boulders or lumps of clay larger than 3 inches, or other undesirable material. No forming material shall be buried.

B. Backfill against concrete shall be clean fill (free of salt contamination) as approved by Engineer, and shall be obtained by Contractor from sources outside the site at no additional costs to the Authority.

C. Concrete

1. Concrete mixes for duct banks shall be in accordance with the Section 03310, Portland Cement Concrete Mixes, Classification 3000 psi, 3/8 inch aggregate for duct banks. Cement shall be Type II Portland Cement conforming to ASTM C150.

D. Waterstops

1. Waterstops shall be installed where shown on M.B.T.A. Plans. Materials and installations shall conform to the Section 03253, M.B.T.A. Construction Standard Specification.

E. Cable Support Hardware

1. Cable racks, support brackets, fiberglass insulators and all other hardware shall meet M.B.T.A. Engineering approval.

F. Concrete Encased Duct Banks.

1. Conduit for underground duct banks shall be glass fiber reinforced epoxy resin pipe of sizes indicated on the contract drawings.

2. Conduit shall be complete with all couplings, adapters, bends and supports as required or shown on the contract drawings. All couplings and fittings shall be the products of the conduit manufacturer. Different fitting manufacturer and conduit manufacturer will not be acceptable.

3. Conduit shall be straight and true and shall be furnished in lengths of 10 or 20 feet. The cross section taken at any point perpendicular to duct shall not vary more than 1/8" form a true circle. Conduits shall be complete with all couplings, adaptors, bends and supports as required or shown on the Contract Plans. All couplings and fittings shall be the products of conduit manufacturer.

4. Fiberglass epoxy conduits shall conform to M.B.T.A. Specification P-180-A "Fiberglass Reinforced Phenolic Conduit" included in the Appendix of these Specifications.

5. The ends of ducts entering manholes shall be provided with end bells. End bells shall be of fiberglass reinforced epoxy compound, manufactured using the same process used for manufacturing the conduit and machined to the proper flare. End bells are required to provide smooth and rounded surfaces at the edge of the duct to prevent injury to the cable during normal movement.

6. Duct spacers or separators shall be of plastic, suitable for the type of application and shall be of the size required for size of duct, configuration and clearances as shown on the Contract Plans.

7. Conduits exiting the concrete slabs must transition to Rigid Galvanized Steel (RGS) conduit below the slab so only RGS is visible above the slab. Use RGS conduits in slab where shown on drawings. If in slab conduit details do not specify conduit type use FRE. Conduits run out of concrete slabs must be RGS with threaded fittings.

8. Contractors shall submit, within 30 days after award of the Contract, shop drawings of the fiberglass epoxy conduit, fittings and spacers for Engineer's approval.

2.02 CONSTRUCTION

A. General

1. Before commencing work, the Contractor shall familiarize himself with the Contract Plans indicating the work to be done under this Section.

2. The Contract Plans are an integral part of these specifications but it shall be understood that the duct and cable systems are shown schematically only. The locations shown on the Contract Plans which are not definitely fixed by dimensions are approximate and exact locations shall be determined at the site to secure the best conditions and results and shall have approval of the Authority's Engineer prior to installation.

3. If the field conditions warrant change in the routing or configuration of duct banks, Contractors shall

obtain Engineer's approval for such field changes. Such changes shall be done at no additional cost to the Authority and the Contract Price is deemed to be inclusive of such changes. All field changes shall be noted and shown on the as-built drawings.

B. Clearing

1. Clearing and site preparation before commencing work shall conform to all applicable requirements, as determined by the Engineer, specified in the M.B.T.A. Construction Standard Specification Section 02200.

C. Concrete

1. All concrete work shall be in accordance with the M.B.T.A. Construction Standard Specification Section 03300. Concrete shall be placed throughout the length of the duct bank. Construction joints in duct banks shall be keyed or interlocked in order not to produce a vertical break and weakening of the structure. The ends of the conduits shall be plugged if the job is halted for any period of time such as overnight. The concrete shall be well vibrated and compacted with a pencil type vibrator to sufficiently insure complete fill without voids between and underneath the ducts.

D. Reinforcing Steel

1. Reinforcing steel shall be placed as requested. Reinforcing steel shall not be placed between the ducts. Cross-tie members of reinforcing shall be installed so that they will not form loops around any duct or group of ducts.

2.03 INSTALLATION

A. Concrete Duct Banks

1. The ducts and conduits shall be installed with a minimum continuous slope of six inches per one hundred feet.

2. The trench for underground duct banks shall be excavated or cut in existing slabs and elevations and directions of pitch of ducts determined so as to give required cover. Trenches shall have the bottom tamped firm and even. If due to sub-surface conditions, the cover will be less than specified on the drawings, the Contractor shall notify the Engineer who will issue the proper instructions for each instance.

3. Changes in directions in duct runs exceeding a total of ten degrees, either vertical or horizontal, shall be accomplished by long sweep bends having a minimum radius of curvature of 25 feet. The bends shall be made by installing five-degree angle couplings between successive short lengths of conduit. At the end of the conduit run, manufactured elbows having a minimum radius of 60 inches may be used. Standard radius bends, elbows or other fittings shall not be used.

4. The fiberglass epoxy conduit shall be laid in the trench in the designed formation using precast concrete block or plastic spacers for spacing conduit. Metallic spacers shall not be used. Joints in conduits shall be staggered at least six inches horizontally and vertically. Conduits between joints shall be supported by at least two separators. Reinforcing around the conduit envelope, spaced as specified, at the rim of the envelope and reinforcing along the ducts shall be provided as shown on the Contract Plans.

5. Conduit shall be installed in not less than ten-foot lengths, except at the ends of runs or at bends. Conduit shall be free of cracks and chipped ends. The Contractor shall furnish and have available at

the job site a sufficient quantity of conduit so that cracked pieces or those with chipped ends may be discarded.

6. FRE couplings and fittings shall be of the slip-on, friction type.

7. All field cuts of fiberglass conduit shall be made with a hack-saw. Cuts shall be smooth and square to conduit axis. The cut end of conduit shall be reamed smooth. Field-cut conduits shall be joined with double-ended couplings designed for the purpose.

8. Repairs to conduits will not be permitted. All individual lengths of broken, cracked, chipped or impaired conduit shall be removed and replaced with new conduit.

9. When changes in the formation of a bank of conduits within a duct run are necessary, the transition shall be accomplished in as straight an alignment as possible, maintaining continuous earth support under the conduits.

10. After the conduits and reinforcements are in place with proper spacing and joints made tight, the entire assembly is raised from the bottom of the trench on concrete or plastic blocks placed at intervals, so that concrete bed of specified depth is formed below the conduit assembly. The entire conduit envelope assembly shall be firmly anchored in position to prevent "floating" when concrete is placed.

11. After the installation is complete, a flexible duct rodding device shall be passed through each completed conduit to check for continuity and cleanliness.

12. Following the duct rodding device a mandrel not less than 1/4" smaller than the inside diameter of the conduit preceded by a wire brush tied to the same string shall be pulled through the conduit once in each direction. If difficulty is encountered in passage of the duct rodding device or mandrel, a series of wire brushes shall be drawn through the conduit, once in each direction, using a trailing line. The wire brushes shall be 1/8" less in diameter than the diameter of the conduit, and if the correct size cannot be passed through on the initial attempt, the operation must be repeated until accomplished as specified. When the conduit is partially or fully obstructed with mud, dirt, or gravel, the duct shall be flushed clean by use of water from a long flushing nozzle attached to a water hose which shall be pushed into the conduit and applied until the conduit is clear. After cleaning, the procedure outlined above for rodding and wire brushing shall be followed. Any damaged conduit shall be replaced with a new conduit.

13. After all obstructions have been removed and the conduits wire brushed clean, a nylon cord of suitable strength shall be threaded in each conduit of duct bank and tied to the nearest pulling eye with a six foot length left at each end. Immediately upon completion of threading the conduit with a nylon cord, both ends of the conduit shall be plugged to prevent entry of foreign matter before the cables are pulled.

14. Forty Eight hours prior to pouring the concrete for each electrical duct bank the Contractor is required to inform the MBTA Field Engineer. The Field Engineer inspection is required to insure the conduit is installed per the manufacturers instructions.

B. As-Built Drawings - Electrical Duct Banks

1. The final submittal of as-built drawings on mylars, as specified in Section 01300 of Division I - General Requirements, shall be submitted as the respective portion is completed and shall provide such details of duct lines and all other underground utilities.

PART 3 - EXECUTION

NOT USED

PART 4 - MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Separate measurement and payment will not be made for Underground Ductbanks of this Section. All work shall be installed complete in place with all cost included in the Contract Lump Sum Price for the work as indicated herein.

B. All underground Ductbank work shall include the setting, forming, conduit, cleaning/rodding, supporting and placement of concrete.

C. Underground Ductbanks shall include surface mounted conduits encased in concrete similar to protection of main feeders along the tunnel wall.

4.02 PAYMENT

A. Payment for the Underground Ductbanks and manholes specified in this Section shall be included as part of the Contract Lump Sum Price listed below.

B. Underground Ductbanks as described herein shall not include conduit embedded in structural slabs or walls. See Section 16120 for measurement and payment of Conduit.

4.03 PAYMENT ITEMS

Item No.	Item Description	Unit
1619.225	CONCRETE DUCTBANK	LF

END OF SECTION

SECTION 16311

DOUBLE-ENDED UNIT SUBSTATION
TUNNEL VENTILATION SHAFT B-2

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing, installing, connecting, testing, energizing and commissioning a double-ended unit substation assembly at Unit Substation B2 to replace the existing single unit substation.

1. Double-ended unit substation and load interrupter switches specified under this Section shall conform to the requirements specified herein, applicable ANSI and NEMA Standards, NEC Code and MBTA Standard Specification P-169 - "Specification for Unit-Substation General Design Criteria".

2. The double-ended unit substation assemblies specified in this Section are intended to supply the 480Y/277 volt ac load requirements of the ventilation shaft and all auxiliary loads shown on the contract drawings.

3. Two primary medium voltage feeders shall be provided to the double-ended unit substation from existing MBTA 13.8 kV airport medium voltage distribution system. Refer to the Contract Drawings for incoming service feeder installation and actual MBTA feeder designations.

4. The dimensions of equipment shown on the Contract Drawings are the maximum dimensions that are acceptable to the Authority. Strictly, adhere to physical layouts on plans, elevations and sections shown on the Contract Documents.

5. In addition to the factory testing individual equipment as specified in Article 3.05 of this Section, the double-ended unit substation shall be fully assembled at the factory, including all interconnection wiring, for inspection and witness testing by the Engineer and the Authority. The equipment shall be disassembled for packing and shipping. Each wire/cable disconnected shall be properly tagged and protected for shipment. Provide all supports and bracing required to prevent damage to the equipment during shipping.

6. The shipping sections shall be such as to permit transporting into and out of the existing Electrical Room at Unit Substation B2 without modifications to building equipment or demolition satging sequence shown on the plans.

7. The Engineer and the Authority shall witness factory testing.

B. SCADA

1. This specification covers the furnishing of provisions in the unit substation for interfacing with the Systemwide MBTA Supervisory Control and Data Acquisition (SCADA) System specified in Section 16313.

2. The double-ended unit-substation shall be wired to interface with the existing MBTA's SCADA System. The manufacturer shall prepare point-to-point wiring diagrams from each compartment within the unit-substation to the terminal strip within the STB panels and RTU cabinet. Each terminal shall

be labeled from its source to point of termination. The electrical contractor shall provide all wiring from the unit-substation to the STB panel. The wiring shall be extended from this panel to a second main STB panel and / or to the SCADA System RTU cabinet. Refer to the contract drawings and specification for a list of all the unit substation SCADA points. The contractor shall provide wiring and terminals for an additional 50 percent spare points between the unit-substation and each STB panel and RTU cabinet. The contractor shall be responsible for submitting a list of the unit substation SCADA points to be monitored and spares.

3. The Contractor shall be responsible for coordinating the complete installation.

1.02 INTERFACES

A. See Sections 16050 and 16070, and Standard MBTA Specifications for general interface requirements.

B. The Contractor shall coordinate all connections of equipment furnished under this Contract with existing equipment or with other equipment being furnished as part of this Contract.

1.03 QUALITY CONTROL

A. The design of the equipment shall provide features for personnel safety during operation, maintenance, and repair.

B. All equipment and materials supplied by the Contractor shall be new, of recent manufacture and of highest grade as specified. They shall be resistant to moisture and corrosion to withstand their operating environment and site conditions with minimum maintenance and long life.

C. Workmanship: Prepare all equipment surfaces so that they are smooth and free of gaps, burrs, sharp edges, wrinkles, waves, blemishes, or other unsightly defects which would detract from a neat appearing finished product. Enclosing structures shall have sufficient structural reinforcements to maintain the vertical and horizontal plane true and plumb and to restrain vibration. The manufacturer shall provide necessary supports and stiffeners to maintain rigidity during shipment, installation, and operation.

D. Major electrical equipment and materials furnished under this Contract shall be the product of a single manufacturer. The manufacturer shall maintain a service organization within a reasonable distance from the project, which is properly staffed and equipped to make repairs as required within twenty-four hours.

E. Materials and equipment shall be the products of a manufacturer regularly engaged in the design and fabrication of the unit-substations. The manufacturer shall have such products of comparable capacity and function to that specified in satisfactory use for a minimum of five years prior to bid opening. The manufacturer of the internal equipment (switches, circuit breakers, transformer, etc.) shall also be the manufacturer of the structure, enclosure and all bus work.

F. Acceptable Manufacturers

1. Siemens

2. General Electric

3. Square D

4. Westinghouse/Cutler-Hammer

5. ABB Power

G. The Contractor shall be responsible for the proper application and satisfactory operation of each section and component furnished under this Section of the Specification. Proposed designs and materials, which in the judgement of the Engineer would require unreasonable and/or frequent maintenance, repair or replacement, are not acceptable.

1.04 WARRANTY OF EQUIPMENT

A. Substation

1. The manufacturer shall warrant all equipment furnished under this Section to be free from defects in materials and workmanship for a period of 1 year from date of Authority acceptance.

1.05 STANDARDS

A. The contractor shall comply with the regulatory requirements listed in the General Provisions, Section 16050 of MBTA Standard Specifications as dated in 1980, Section 16050 Special Provisions for this contract and other Standards listed below.

B. Standards

1. All major electrical equipment furnished under this Contract shall be in accordance with the latest applicable standards of NEMA, IEEE, ANSI, AAR, ICEA, OSHA, and UL with regard to Material, Design, Construction and Testing, except for variations as specified in this Specification. The standards applicable shall include but not be limited to the following:

ANSI C37.13	Low Voltage AC Power Circuit Breakers Used in Enclosures
ANSI C37.35	Guide for the Application, Installation, Operation, and Maintenance of High Voltage Air Disconnecting and Load Interrupted Switches
ANSI C37.16	Preferred Ratings, Related Requirements, and Application Recommendations for Low Voltage Power Circuit Breakers and AC Power Circuit Protectors
ANSI C37.17	Standard for Trip Devices for AC and General Purpose DC Low-Voltage Power Circuit Breakers
ANSI C37.20.1	Standard for Metal-Enclosed Low Voltage Power Circuit Breaker Switchgear
ANSI C37.40	Service Conditions and Definition for AC High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches and Accessories
ANSI C37.51	Standard for Conformance Testing of Metal-Enclosed Low-Voltage AC Power Circuit Breaker Switchgear Assemblies
ANSI C37.90	Relays and Relay Systems Associated with Electric Power Apparatus

ANSI C39.1	Requirements for Electrical Analog Indicating Instruments
ANSI C57.12.01	General Requirements for Dry-Type Distribution and Power Transformers
ANSI C57.12.10	Requirements for Transformers 13.8 kV and Below
ANSI C57.12.51	Distribution Transformers above 501 kVA, Three- Phase, Ventilated Dry Type
ANSI C57.12.91	Test Code for Dry-Type Distribution and Power Transformers
ANSI C57.13	Requirements for Instrument Transformers
ANSI C68.1	Dielectric Test Techniques (IEEE #4, ANSI/IEEE STD4-1978)
ANSI B1.1	Unified Inch Screw Threads
ANSI B1.10	Unified Miniature Screw Threads
ANSI Z55.1.61	Gray Finishes, Light Gray Color Chip No. 61
ICEA S-68-516	Ethylene-Propylene-Rubber Insulated Wire and Cable (NEMA WC-8) for the Transmission and Distribution of Electrical Energy
NEMA SG 3	Low Voltage Power Circuit Breakers
NEMA SG 5	Power Switchgear Assemblies
NEMA ST 20	Dry Type Transformers for General Applications
UL-44	Underwriters Laboratories, Inc., Flame Retardant Properties Test, for Rubber-Like Insulated Wire
UL-508	Underwriters Laboratories, Inc., Industrial Control Equipment

2. Where any requirements specified herein or shown on Contract Plans exceed the above listed standards, the Contractor shall adhere to the higher standard. In case of conflict in requirements between two or more standards, decision of Engineer shall be final.

C. Special Conditions

1. If Non-U.S. suppliers are proposed by the Contractor, it shall be their responsibility to provide equivalent British, European, Japanese, IEC or EU standards and prove that the proposed equipment complies with referenced U. S. standards and codes. Tabulation shall be provided citing the comparison between the applicable U.S. and the equivalent Non-U.S. standards. In addition, the Non-U.S. suppliers shall indicate where U.S. standards are not met for evaluation and approval by the Engineer. Failure to identify equivalent comparisons, standards or codes not satisfied by the equipment being furnished will void all approvals. The contractor shall remove all the equipment at there expense and shall be financially responsible for all delays to the project.

2. All equipment and materials furnished under Division 16 shall conform to applicable Federal, State or Municipal Laws for ordinances, and if any requirement shown or specified conflicts with such laws or ordinances, the Contractor shall make such changes as are necessary to meet said requirements. The cost of such changes shall be borne by the Contractor and shall be included in the Contractor's original bid. Where any standards shown on the Contract Drawings or specified herein exceed the minimum standards set by law, the Contractor shall adhere to the higher standard.

3. Where materials or equipment are specified to conform to the standards of the Underwriters Laboratories, Inc., or to be constructed or tested, in accordance with the standards of the National Electrical Manufacturers Association or American National Standards Institute, the Contractor shall submit proof that the item furnished conforms to such requirements. The label of, or listing by the Underwriters Laboratories, Inc. shall be acceptable as sufficient evidence that the item is in accordance with the Underwriters' Laboratories standard. A Company listed as a member company of NEMA for an item under consideration shall be acceptable as sufficient evidence that the item conforms to the requirements of the National Electrical Manufacturers Association. In lieu of such stamp or certification label listing, the Contractor may submit a written certificate from any nationally recognized testing agency adequately equipped and competent to perform such services, stating that the items have been tested and that the units conform to the requirements listed herein before, including methods of testing of the specified agencies. Conformance with the agency requirement does not relieve the item from complying with any other requirements of the Specifications. The Contractor shall provide written notification 14 days prior to referenced witness tests. Certifications for testing instead of witness tests are not acceptable.

4. The equipment of this section shall be properly packaged for the shipping and handling required for the project. Such items as individual component packaging, layover packaging, crane-hoist packaging and the like shall be provided as required.

1.06 SUBMITTALS

A. Also refer to Sections 01300, Submittals, Section 01700, Contract Closeout, and Section for Drawings, electrical equipment and Tracings for submittal requirements. All drawings, shop drawings, wiring diagrams, SCADA wiring, STB drawings, fire alarm system, HVAC systems, and the power system shall be provided under As-Built, using the latest AutoCad Version software -standard sheets shall be 24" x 36", 4 mil Mylar and an electronic AutoCad Version file per diskette for each drawing.

B. Submittals shall be made in compliance with the Contract requirements.

C. The following information shall be submitted as a minimum:

1. Master drawing index.
2. Front view elevation.
3. Floor plan.
4. Top view.
5. One-Line Diagram.
6. Schematic diagram including point-to-point SCADA Diagrams indicating terminal arrangements.
7. Nameplate schedule/diagram.
8. Component list.
9. Fully dimensioned Conduit entry/exit locations.
10. Assembly ratings including:

    a. Short circuit rating.

b. Voltage.
c. Continuous current.
d. Basic Impulse level for equipment over 600 volts.
e. Rated kVA.

11. Major component ratings including:

a. Voltage.
b. Continuous current.
c. Interrupting ratings.

12. Cable terminal sizes, number of terminals per phase.
13. Connection details between close-coupled assemblies.
14. Composite floor plan of close-coupled assemblies.
15. Impedance for transformers.
16. Location of all devices in each compartment including relays, terminal blocks, instruments and SCADA System Panels

E. The following additional information shall be submitted:

1. Connection and arrangements.
2. Composite floor plan.
3. Connection details between coupled assemblies.

F. The following product information shall be submitted:

1. Descriptive bulletins, all originals.
2. Product sheets, all originals

G. The following information shall be submitted for record purposes prior to final payment.

1. Final as-built drawings and information for items listed section 1.06. Four mil Mylar's and the latest AutoCad Version of each drawing on diskette.
2. Wiring diagrams.
3. Certified production and field test reports.
4. Installation information.
5. Seismic certification and equipment anchorage details.
6. Maintenance and Trouble Shooting Manuals

1.07 SPECIAL TOOLS AND HANDLING PROVISIONS

A. Furnish and deliver with the equipment all special tools and equipment handling devices as recommended by the component manufacturers, for the adjustment and maintenance of all equipment furnished under these specifications. Special tools are defined as tools not readily available on the open market.

1.08 TESTING

A. Double-ended unit substation shall be tested in the field after installation is completed. The tests shall be performed by an independent testing company retained by the Electrical Contractor. The Electrical Contractor shall submit the name and qualifications of the independent testing company to the Engineer and the Authority for approval. The independent testing contractor shall be a full member of NETA or an equivalent agency as being qualified to perform the required test for this project. .All test results shall be submitted on standard NETA forms.

B. The independent testing contractor shall prepare and submit a bound test report. The test report shall indicate the following:

1. Tests performed
2. Individual performing test, witnesses, dates performed
3. Equipment manufacturers, sizes, type, etc.
4. Results of tests
5. Manufacturer's recommended values
6. Remarks and conclusions.

C. The test report shall include a summary, signed and certified by a principal of the testing firm indicating that the results are complete and accurate, and that all results are acceptable, and include a recommendation that the system is ready for energization.

D. The independent testing company shall act fully in the interest of the Authority, and shall indicate any anomalies, unusual conditions, or items which would otherwise impair the operation of the system, or the quality of the installation. Repair or replace any work, which is unacceptable to allow the independent testing contractor to certify the system.

E. Results shall be recorded and submitted to the Engineer. Equipment not approved shall be replaced and retested at no cost to the Authority.

F. Within five (5) working days of testing and submission of the certified report, the system may be energized, subject to the approval of the Authority.

G. The testing company shall furnish all labor and materials including all instruments and required appurtenances to perform the tests and inspections.

H. The field tests for unit-substations, including transformers are described in Section 16950 "Electrical Acceptance Tests".

I. The independent testing contractor shall certify the equipment is ready for energization.

PART 2 - PRODUCTS

2.01 GENERAL REQUIREMENTS

A. Equipment Environment

1. The MBTA unit-substation shall be installed in the location shown on the drawings. The unit-substation distributes ac power to essential equipment, such as vent shaft fans, lighting, heaters,

miscellaneous mechanical, electrical and communication loads. MBTA substation is located in an area that presently has severe environmental problems, such as extreme heat, electrical noise, rail dust, moisture, and water leaks.

2. Double-ended unit substation specified in this Section shall be designed for operation in an environment of zero to 40 degrees C ambient temperature.

3. The sound level of the unit shall not exceed the limits specified in ANSI C89.2 and NEMA ST-20.

4. The equipment shall be designed to resist dynamic earthquake loading based on the Massachusetts State Building Code.

5. The equipment shall be located in the Electrical Room at the existing Blue Line Ventilation Shaft, and thus shall be subject to and designed to withstand vibrations generally expected from operation of trains on the track and emergency response vehicles. The building is being modified to provide space for the installation of the new unit substation.

6. The equipment shall also be subjected to dust and exposure to outdoor conditions during the construction of the extension to the existing building. The Contractor shall coordinate the installation of the new substation and the demolition of the existing substation with the General Contractor's modification to the building and protect all equipment as required.

7. The double-ended unit substation enclosure shall be rated NEMA 12, gasketed.

B. Existing Ventilation Shaft Electrical Room

1. Working clearances around the Substation shown on the drawings are minimum.

2. Install bare copper ground buses (1/4" X 2" minimum) as shown on the drawings, on 1.5" to 2" standoffs, mounted approximately 30" AFF. This ground bus is to be connected to the ground bus inside all the electrical equipment. This ground bus shall also be tied into the existing main service ground.

3. Provide not less than (3) connections of 4/0 AWG RHW insulated, stranded copper cable from the substation room ground bus to the double-ended unit-substation ground bus and switchgear ground bus, in minimum 2" conduit, overhead, exposed.

C. Service Conditions

1. 13.8 kV, 60 Hz three-phase, ac power to the incoming load break switch units shall be supplied from new medium voltage feeders as shown on the drawings and specified in Section 16120.

2. It is expected that the maximum short circuit capacity of the 13.8 kV ac source, from MBTA network, at the incoming feeder terminals of load interrupter switch shall not exceed 750 MVA at this location with an X/R ratio of 8.

D. SCADA System Provisions

1. The contractor shall provide the equipment vendor with a complete listing of all SCADA "points" to be monitored and/or controlled within the double-ended unit-substation. The vendor shall pre-wire all such monitored points to a single set of terminal blocks within the double-ended unit-substation

enclosure, in a front accessible cubicle(s) with door(s). All wiring shall be labeled in accordance with the contract drawings, and the approved contractor submittals. All terminal blocks shall be as specified in this section.

2.02 DOUBLE-ENDED UNIT-SUBSTATION SWITCHGEAR - GENERAL

A. The double-ended unit substation shall consist of two of each of the following sections:

1. 13.8 kV ac incoming line fused load break switch with transformer primary overcurrent protection.

2. Ventilated, dry, fully epoxy cast coil type transformer section.

3. 480Y/277-volt ac secondary distribution section.

All the above sections of each double-ended unit-substation shall be designed and assembled together, as shown on the contract drawings with transition units, where required, to form a mechanically and electrically coordinated, rigid, free standing dead front assembly. The sections of the assembly shall be mounted on a common base channel and rigidly bolted to each other. Each section of the assembly shall be suitable for lifting as a single unit in one piece (without base channel) without the section being distorted or otherwise damaged. Each section shall consist of rigid self- supporting and self-contained electrically welded or rigidly bolted steel structures enclosed with not less than 12 gauge formed steel sheets. All sections shall be of the same depth and height arranged for front lineup.

B. Operating Philosophy

1. The Switchgear equipment furnished by the Contractor shall be provided with protective, control and interlocking features to safeguard the various equipment and to permit both local and/or supervisory control as specified herein and as shown on the contract drawings. The Specification and contract drawings indicate the basic protection and control requirements, which shall be adhered to.

2. The following device numbers are used for specifying the control and supervision scheme. These device numbers shall also be used by the Contractor in the schematics and wiring diagrams, arrangement drawings and bill of materials:

DEVICE NO.	FUNCTION
1	AC circuit breaker local control switch
27	AC under voltage relay
30	Annunciator
43	AC breaker control mode selector switch
47	Phase sequence and undervoltage relay
47X	Auxiliary relay
49TR, TH	Transformer winding over temperature device alarm and TRIP
52	AC circuit breaker
74	Alarm relay
83	Automatic Transfer
86	Lockout relay
89	Load interrupter switch, fused or unfused
201C	Supervisory interposing relay - close
201T	Supervisory interposing relay - trip

C. Protective Device Coordination

1. The Contractor shall furnish protective devices in the Switchgear equipment as listed elsewhere in this Section, or as shown on the contract drawings, or as may be required, to provide reliable coordinated protection for the system. All such devices shall be adjustable and shall be factory calibrated to provide the general scheme of protection outlined below. The Contractor shall submit to the Engineer, for approval, the recommended settings of the protective devices, and show the settings on log-log paper for graphic proof of the required device coordination.

2. Transformer secondary (main) circuit breakers shall provide:

   a. Protection of transformer windings from low voltage Switchgear faults.

   b. Protection of low voltage switchgear and transformer from overheating due to overload.

   c. Backup protection for distribution circuit breakers.

3. The following transformer protective device shall cause the automatic tripping of the secondary circuit breaker through the lockout relay (Device 86). The lockout relay shall cause the lockout of circuit breaker in open position until the lockout relay is manually reset. The lockout relay, through its "b" contact, shall create loss of voltage condition to phase sequence and undervoltage relay (Device 47) thus setting automatic transfer scheme into operation:

   a. Transformer winding hot spot over temperature second step (Device 49^{TH} and 49 TR).

4. The following conditions shall cause the automatic tripping of the secondary circuit breaker:

   a. Fault on distribution feeders - phase and ground fault not cleared by distribution circuit breakers.

   b. Overcurrent condition on 480 V switchgear bus.

5. Contractor shall furnish phase and ground selective coordination curves for the system starting from 13.8 kV primary circuit fuse of the transformer through low voltage secondary circuit breaker, bus tie circuit breaker and distribution circuit breakers. Protective device coordination curves shall be submitted on K&E Co. Paper 48-5257, showing relay, trip device coordination of all equipment. The Contractor shall furnish details of protection provided in the 13.8 kV switchgear at substations or data on utility feeders required for preparation of coordination curves. Refer to Section 16951 for short circuit and coordination study requirements.

6. Contractor shall provide ground fault protection scheme meeting the requirements of National Electrical Code for service entrance equipment with a transfer scheme. The preferred protection scheme is by neutral relaying. Contractor shall submit the proposed scheme for Engineer's approval along with the shop drawings of equipment.

D. Doors

Doors shall be formed of sheet steel and shall be properly reinforced against distortions by suitable flanges and stiffening members. Hinges shall be of heavy-duty lift-off, of a type approved by the Engineer. All doors shall be securely fastened in the closed position with a minimum of two latches easily opened without the use of tools unless noted to be bolted. Doors shall be provided with stops to hold them securely in the open position.

1. All load break switch cubicles shall have hinged doors front and rear. The front door shall be equipped with pad lockable capabilities. The rear door shall be hinged on one side, bolted on the other, and come with the hardware installed so that a padlock may be installed later.

2. All transformer enclosures shall have hinged doors front and rear, hinged on one side and bolted on the other and have the capability to be locked with a padlock.

3. All switchgear cubicles shall have hinged doors front and rear, and have the capability to be locked with a padlock. Front doors shall have hand screws; rear doors shall be bolted.

E. Nameplates

1. Contractor shall provide nameplates on the front and rear of the load break switch section and transformer section, engraved "Danger, 13,800 VOLTS". The nameplate shall have white letters, 2 inches high, minimum, on red background. Nameplates shall be on each door of each section.

2. Each major component of equipment shall have, as a minimum, the manufacturer's name, address, and catalog number, model, style or type on a nameplate securely attached to the item in an area easily accessible to normal visual demands by maintenance and service personnel. Nameplates for electrical apparatus shall conform to the referenced standards and as specified elsewhere in this Specification.

3. Each switchgear assembly, switch unit, circuit breaker and metering units, transformer, terminal box, and all panel mounted and individually mounted equipment and devices shall be provided with nameplates for proper identification. Door mounted devices shall also be identified in the rear with the designations indicated on manufacturer's connection diagrams. Internally mounted devices shall be similarly identified with nameplates and manufacturer's connection diagram designations.

4. Nameplates identifying major equipment shall have lettering two inches high, minimum. Two nameplates shall be provided, one on front, the second on the rear of the equipment, as follows:

   Line 1 - Equipment Designation
   Line 2 - Equipment Source Feeder or Buss
   Line 3 - Equipment Load Feeder or Buss

   For Example: 89-1
   52 FX-1
   0-12 - 7VSF

5. Nameplates identifying circuit breaker and auxiliary units shall have lettering one inch high, minimum. Inscription shall include circuit breaker number and service. One nameplate shall be provided on front, the second on the rear of each unit.

6. Nameplates for panelboards, terminal boxes and similar equipment shall have lettering 3/4 inch high, minimum.

7. Nameplates for door mounted and internal panel mounted relays, meters, control and instrument switches, fuses and auxiliary devices and individually-mounted circuit breakers, disconnect switches, etc., shall have 1/4 inch, minimum, lettering. For protective and auxiliary relays, the nameplate inscription shall include device number and function. Nameplates for fuses shall note the type and rating of fuse, polarity and identify the circuit.

8. All nameplates shall be laminated plastic with dull white surface and black core unless otherwise specified. Letters shall be engraved through outer layer to expose black core. All exposed edges shall be beveled. Nameplates shall be fastened with two stainless steel machine screws. Use of self-tapping screws or adhesives shall not be permitted.

9. The legends of all nameplates shall be submitted to the Engineer for approval.

10. Provide nameplates on all devices, meters, switchgear, and cubicles. The backside of each individual cubicle must be labeled. The MBTA's Power Systems and Equipment Division shall approve all nomenclature.

2.03 BUS AND BUS CONNECTIONS

A. The buses within equipment supplied by the Contractor shall be fabricated of high conductivity radius edge rectangular copper bars as specified herein. Buses shall be designed to carry rated currents without exceeding the maximum allowable temperature rise as specified in ANSI, NEMA and IEEE standards when operating at specified rated overloads. Bus connections and joints shall have an ampacity equal to that of the bus ampacity, and fabricated so that there shall be no loss of conductivity during the life of the equipment.

B. The entire contact area of all bolted current carrying connections in copper buses shall be factory silver-plated. Ring-plated method of silver plating and tin-plated contact surfaces shall not be acceptable. Silicon bronze bolts, nuts and Belleville washers, or approved equal shall be used. Connections shall be made with a minimum of two 1/2"-13 bolts at each end of the joint. Provide with installation materials, manufacturer's required bus joint hardware torque data. All hardware torquing shall be done in the presence of the Engineer.

C. Phase sequence of buses, leads and terminals in the equipment shall be A, B, C top to bottom, left to right and front to rear. Phases shall be identified per NEMA Standards and as specified for buses in this Section.

D. Clearly visible permanent phase identification (A, B, C, Neutral or ground) of each bus inside the switchgear shall be provided. Also, nameplates specifying whether the buses are line side or load side shall be provided.

E. All 13.8 kV bus shall be fully epoxy insulated, while maintaining uninsulated bus spacing. All 600-volt (nominal) bussing shall either be dip insulated or heat shrink insulated, while maintaining uninsulated bus spacing. Sleeve type insulation is not acceptable. All bus, including main and run-back buses shall be insulated.

F. Following field connection, all bus joints shall be insulated with suitable "boot" type insulation.

2.04 POWER AND GROUND CONNECTORS

A. All terminal lugs furnished for power and ground cables shall be heavy duty, bolted type, of high copper content alloy, complete with silicon bronze bolts, nuts and lockwashers. Lugs shall have tongues with either two or four 1/2"-13 bolts, as specified, spaced per standard NEMA drillings, and die crimped cable. Contact surfaces shall be machined smooth and silver-plated.

B. A continuous copper ground bus 2-inch x ¼-inch, or larger, shall be provided through the entire length of the unit substation. The enclosure of each section shall be grounded to this bus. Bolted type terminal lugs with two-bolt tongue shall be provided for field connection to the service ground. The connectors shall be suitable for stranded copper ground cable sized as shown on the drawings.

C. Contractor shall provide means of grounding incoming 15 kV line side and main buses for maintenance purposes without actually entering inside the cubicles and installing clamps on the buses.

D. Ground all medium voltage cable sheaths to the double-ended unit-substation ground bus.

2.05 SURGE ARRESTERS

A. Surge arresters associated with 15 kV system shall be of the intermediate class or equivalent, suitable for installation in metal clad switchgear. Arresters shall be rated for application on the specific voltage system on which it is being used. The manufacturer shall be responsible to coordinate the size of the surge arrestors for the system being used, on a nominal 13.8 kV, effectively grounded neutral system. The surge arresters shall not reduce the BIL or short circuit ratings of the equipment, and are subject to the approval of the Engineer.

B. Distribution class arresters are not acceptable for installation in 15 kV switchgear.

2.06 POTHEADS

A. Potheads for 15 kV cable shall be indoor, three-conductor, soldered-joint type, suitable for terminating three-conductor, shielded cable specified in section 16120. Potheads shall have cast bodies of non-ferrous material complete with uncut wiping sleeve. Insulators shall be of high strength wet-process porcelain, rated 15 kV, designed to withstand an impulse test of 110 kV.

B. Potheads shall be mounted on split adapter plate to facilitate removal. Bodies of potheads at 15 kV switchgear for incoming feeders shall be insulated from switchgear structure.

C. Potheads shall be sized for the incoming medium voltage cables.

2.07 KEY INTERLOCK SYSTEMS

A. Tumbler settings of locks shall be different for each interlock system. Interlock scheme and number of keys to be supplied shall be as shown on the contract drawings. Additional keys shall be turned over to the Authority.

B. Kirk-key Interlocking shall be installed between each interrupter switch in the Unit-Substations B2 and Maverick Station and the existing 13.8 kV switchgear at the Airport. Keying shall be such that the door of interrupter switch in the unit-substation cannot open unless the breaker in the 13.8 kV load interrupter or circuit breaker at Maverick Station B3 is opened first, key removed from the 13.8kV load interrupter or circuit breaker and brought to the interrupter switch at the unit-substation.

C. Each primary interrupter switch at Unit-Substation shall be provided with a key interlock system to prevent operation of the interrupter switch in either direction, unless the associated secondary main circuit breaker is open. To open the interrupter switch, the following operations must be performed:

1. Open the secondary main circuit breaker at the unit-substation. The captive key at the circuit breaker is now free to be turned and removed. Turning of the key shall lock the circuit breaker in open position.

2. Open the primary circuit breaker feeding the unit-substation. The captive key at the circuit breaker is now free to be turned and removed. Turning of the key shall lock the circuit breaker in open position.

3. Insert both keys in the locks at the interrupter switch and turn to unlock the switch operating mechanism. Keys are now held captive.

4. The interrupter switch can now be opened.

5. Reverse sequence to restore service.

D. In addition, each interrupter switch shall be provided with mechanical interlock to prevent opening of the front door when the interrupter switch is in the closed position. Kirk-key interlock instead of the mechanical interlock shall not be acceptable. It is the MBTA's intention that the door of the primary interrupter switch be prevented from opening unless the line and load side of the switch are de-energized, the upstream circuit breaker is in the open position and the circuit breaker Kirk key removed and brought to the interrupter switch to open the door of that switch. This insertion of the circuit breaker key shall be the final step for the Kirk key movement.

E. The contractor shall completely coordinate all Kirk-keying to verify that the scheme is provided as specified.

2.08 RELAYS, SWITCHES AND DEVICES

A. General

1. Type of relays, switches and devices used in the control and supervision of the supplied equipment shall have proven record of successful operation in similar application to the satisfaction of the Engineer.

B. Relays and Meters

1. All protective relays except solid-state relays where approved by the Engineer and watt-hour meters shall be of draw-out construction, provided with semi-flush mounting cases. Relays shall be connected to external wiring through built-in test switches or connection blocks arranged to allow in-case testing of the relay. The protective relays shall be rated for 120 volts ac trip circuit and be provided with manually resettable targets (flags) for each function.

2. All control and auxiliary relays shall be front connected, surface mounting type, with cover, suitable for use in switchgear equipment in accordance with ANSI C37.90. Operating coils of direct current relays shall be suitable for continuous operation between 80 percent and 110 percent of rated voltage and for alternating current relays between 85 percent and 110 percent of rated voltage.

   a. The coils of interposing relays, Devices 201C and 201T, for interfacing with the existing

supervisory system equipment shall be rated for operation on 125-volt ac and shall have a burden of not more than 12.5 watts. Coils shall be provided with surge limiting diodes to suppress noise during operation, which may cause momentary false indication. Contacts shall be rated 30-ampere dc, minimum.

3. All indicating instruments shall be switchboard type, one- percent accuracy; semi-flush mounted having metal scales with black figures on white background. They shall be approximately 4-1/2 inches square with a minimum of 240-degree scale, furnished with anti-glare glass, unless otherwise specified.

4. Ammeters for space heater circuits shall be panel type, two- percent accuracy, semi-flush mounting, approximately 2-1/2 inches square.

5. At the contractor's option, the contractor may provide LED type meters, with the specified accuracy. LED type meters shall be Futura + Series, as by Electro Industries, or equal. Microprocessor based metering packages are not acceptable for this purpose.

C. Switches

1. All control, selector and instrument switches shall be rotary type, provided with properly designated black escutcheon plates, clearly marked with white letters to show operating position, General Electric type SBM, Gould type C77, Westinghouse type W2 or approved equal, unless otherwise specified.

   a. Breaker control switches shall be spring return to normal with escutcheon engraved TRIP-CLOSE, trip counter-clockwise, close clockwise, furnished with target and red pistol grip handle.

   b. Breaker control mode selector switches, Device 43 shall be three-position, maintained contact type with escutcheon engraved LOCAL-OFF-SUPV, off position at 12 o'clock, with black oval handle. Provide one (1) switch for each main and each tie circuit breaker.

   c. Instrument switches shall be maintained contact type, shall have an OFF position and black knurled round handle. Voltmeter switches shall be 7 position. Ammeter switches shall be 4 position.

   d. Selector switch for selecting the mode of operation of the 600 volt system, that is, auto mode or manual mode shall be two position maintained contact type with escutcheon engraved AUTO-MANUAL, with black pistol grip handle.

D. Test Switches

1. Test switches shall be provided for in-service testing and calibration of indicating instruments and other devices not furnished with built-in test devices and for removal of these devices from potential and current circuits without disturbing switchgear wiring. Each test switch shall be provided with a minimum of three poles for potential circuits and six poles for current circuits. Current switches shall be provided with features for short-circuiting current transformer secondaries prior to disconnecting the instruments and devices from current circuits. The individual switch units shall be assembled on an insulated base provided with insulated barriers between each pole. Test switches shall be arranged for semi-flush mounting in front of the switchgear. Contractor shall furnish a set of necessary test plugs and jumper cables with each switchgear assembly.

E. Indicating Lamps

1. All pilot lights shall be 120 V ac push to test type K-30.5 mm, heavy duty, oil tight NEMA type 13 with LED light modules.

2. The LED module shall be a 7-element cluster that provides illumination similar to incandescent illumination. The cap shall be glass of the required color.

3. Indicator colors shall be as follows:

-	Open	green
-	Closed	red
-	System in Manual	white
-	System in Off	white

F. Fuses

1. All fuses for control, auxiliary, and metering circuits shall be located in such a position that they are easily and safety accessible. Fuses shall be of the nonrenewable, cartridge type.

   a. Fuse holders and fuses installed in solidly grounded equipment assemblies shall be rated for 250 volts ac service. Fuses shall have a minimum interrupting rating of 40,000 amperes rms, symmetrical, at 250 volts ac and dc.

2.09 WIRING AND WIRE MARKERS

A. All secondary and control wiring in equipment, including wiring on removable elements of circuit breakers, shall be ICEA type SIS or approved equal stranded tinned copper switchboard wire, rated for a minimum conductor temperature of 90 degrees C. Wire shall be insulated for 600 volts unless otherwise specified. Wire shall comply with UL-44 for flame retardant properties test of thermoplastic insulated wire. Wire crossing hinged joints shall be similar except extra flexible, suitably protected against abrasion. Current and potential transformer secondary wiring and control circuit wiring shall be No. 12 AWG, or larger, unless otherwise specified.

B. Wiring shall be provided with ring type compression terminals with insulated sleeves at each termination. All wiring shall be identified at each termination by printing on wire jacket or on an insulating sleeve. Text shall withstand heat, cold, moisture, etc. Adhesive wire markers are not acceptable. The Contractor shall submit samples of wire markers to the Authority for review.

C. Wiring installed through openings in metal barriers or structural members shall be protected against abrasion by approved grommets.

D. Wire harnesses shall be supported with a bracket fastened to the enclosure via a tack-welded stud or a machine screw using a "shake-proof" washer. Stud shall be welded and/or drilling and tapping for machine screws shall be accomplished before finish paint is applied. Nylon composite tie wraps shall be used for securing harness to the support. Wire support brackets attached to the enclosure with adhesives are not acceptable.

2.10 TERMINAL BLOCKS

A. Circuits requiring external connections shall be factory-wired to terminal blocks, readily accessible for field wiring entering from top. Sufficient number of terminals to satisfy all external connection requirements and 25 percent additional unassigned terminals shall be provided. Terminal blocks shall be heavy-duty, washer-head screw type with insulating barriers between circuits, rated 600 volts, unless otherwise specified, complete with marking strips and plastic covers. Similar terminal blocks, complete with properly tagged jumper wires, shall be provided at each shipping split to facilitate field assembly.

B. Current and potential transformer secondary leads shall be wired directly to terminal blocks before being wired to relaying, metering or control devices. Terminal blocks for current transformer leads shall be short- circuiting type.

C. Control power and instrument transformer secondaries shall be grounded with No. 8 AWG wire running directly to ground bus without intervening splices or terminal blocks.

2.11 FINISH

A. All surfaces and metal work shall be carefully finished to remove sharp edges and burrs.

B. Thoroughly clean all surfaces to be painted and treat with a rust inhibiting phosphatized coating prior to the application of two finish coats of semi-gloss ANSI 61 light gray paint, unless otherwise specified.

C. Two sealed quart cans and two full aerosol cans of matching touch-up paint shall be turned over at acceptance of the unit-substation.

2.12 PRIMARY LOAD BREAK SWITCH, FUSED

A. Load Break Switch

1. Fused load break switch unit shall be furnished with a set of three indoor type power fuses of the self-contained interruption type mounted on tip-out supports suitable for operation on service voltage, 60 hertz system. Fuses shall be of the general purpose current limiting type as defined in ANSI C37.46-1969, having a minimum interrupting rating of 100,000 amperes asymmetrical at rated voltage.

2. Provide glastic insulated phase partitions, with nylon nuts and bolts. Associated hardware such as clips and brackets shall be glastic insulated also. Tie wraps are not acceptable.

3. Fused load break switch shall be of the nominal service voltage class, three-pole, single throw, air break, and stationary type, designed for operation on 60 Hertz, having the following ratings:

-	Nominal three-phase rating of associated switchgear	750 MVA
-	Rated maximum voltage	15.0 kV
-	Rated withstand test voltage:	
	Low frequency (RMS)	36 kV
	Impulse, crest	95 kV
-	Rated continuous current, minimum	600 A
-	Contact interrupting rating, minimum	600 A
-	Rated momentary current, asymmetrical (RMS)	40 kA
-	Three second current carrying capability (RMS)	25 kA
-	Fault closing capability asymmetrical (RMS)	40 kA

4. Fused load break switch shall be of unitized three-pole design, mounted on rigid all welded steel frame to assure positive three-phase operation. Each pole shall be equipped with a main blade and a spring-loaded auxiliary blade operating in an arc chute. All contact surfaces shall be silver-plated.

5. Fused or non-fused interrupter switch shall have manually operated; quick-make, quick-break spring stored energy type operating mechanism. An operating handle shall be provided for manually charging the spring and manually closing and opening the switch. Mechanical indicators shall be provided to indicate the charged condition of the operating mechanism. The indicator shall be visible from the front. The switch shall have only metal-to- metal linkage. No chains or cable shall be used.

6. Provide high strength, non-hygroscopic; track resistant porcelain for bus and switch insulators, and switch drive rod.

7. A flexible copper ground connection shall be provided from the switch-operating lever to the ground bus in the unit.

8. Epoxy insulate all bussing to 15 kV, while maintaining uninsulated bus clearances and spacing.

9. Load side of switch shall be cable connected to transformer primary terminals. Cable shall be unshielded, EPR, 133% insulation rated for 15 kV. Cables shall be routed through individual enclosure bushings of porcelain construction. Adequate plastic cable supports shall be provided such that no lengths of cable over 12" is unsupported.

10. Interrupter switch compartment shall be equipped with a visual means of viewing the position of switchblades without opening section door. Rear door shall also include non-shatterable window, for viewing neon glow tubes.

11. Provide auxiliary switches for indication and alarm circuits. Each interrupter switch unit shall be furnished with a minimum of four "a" and four "b" spare auxiliary switch contacts easily convertible in field. These spare contacts shall be wired to SCADA terminal blocks at the secondary switchgear section.

12. Each of the primary power supply feeder cables shall be installed with two removable neon glow tubes, RS type with antennae per phase for "feeder alive" indication. The glow tubes shall be mounted for observation through windows of non-shatterable material located at a convenient viewing height. The glow tubes and mounting bracket assemblies shall be insulated from the bus and removal of the glow tubes and/or mounting bracket shall not infringe upon the integrity of the bus insulation. The glow tubes shall be arranged to obtain adequate brilliancy for observation in a well-lighted area. The neon glow tube shall not reduce the impulse withstand level of the equipment.

13. Provide surge arresters as shown on plans.

14. Potheads shall be provided, suitable for terminating three-conductor, 15kV, Class H shielded copper cable manufactured per MBTA Standard Specification P-73E. Cable sizes as shown on the drawings.

15. Incoming line section shall be provided with hinged front doors. Front door shall be hard-screw bolted, with interlocks as specified in this section. Rear door shall be bolted, with padlock hasp and staple.

16. Provide thermostatically controlled cubicle space heater with ammeter rated for 120V/250 watts with on/off switch, and blue indicator light. Power shall be from CPT at secondary section.

17. Provide on each phase conductor a 1-inch diameter ground ball stud and cover installed on each phase conductor on the line and the load side of the switch. Also, provide (2) ground balls at ground bus in front section of switch. This shall facilitate grounding of the switch with two 3-way grounding jumpers to a ground bus with its associated ground balls and stud covers located at the bottom front of the cubicle. (A total of 8 ground ball studs and covers per Load Break Switch).

B. Instrument Transformers

1. Instrument transformers shall be of the dry type. Transformers and associated wiring shall have mechanical strength and thermal rating commensurate with the rating of the associated equipment.

2. Voltage transformers for indication and metering shall have ratios as shown on the Contract Drawings, a minimum thermal rating of 1,000 volt amperes with 55 degrees C rise above a room ambient of 40 degrees C, and an accuracy of 0.3 with ANSI standard W, X and Y burdens, 0.6 with Z burdens, and 1.2 with ZZ burdens. Voltage transformers shall be equipped with current limiting primary fuses and shall be mounted on draw-out or tilt-out carriages. The front of the carriages shall be designed to close the section when the transformers are in the operating position. Primary contacts for the draw-out feature shall be of a design, which shall verify continuous positive contact pressure. Carriages shall be of sufficiently rigid design to maintain proper alignment of the primary contacts. Visible grounding devices shall be provided to verify that the draw-out carriage mounted voltage transformer primary terminals are grounded when the carriage is withdrawn. A flexible braided strap shall be provided for bonding the draw-out carriage to the equipment enclosure.

3. All voltage transformer primary circuit connections from bus to the primary fuses shall be of No. 2/0 AWG, minimum, copper wire, fully insulated for 15 kV. Connections from the fuses to the high voltage terminals of the transformers shall be No. 6 AWG minimum, copper wire, fully insulated for 15 kV. Phase-to-phase and phase-to-enclosure distances shall be based on in-air clearances, assuming bare conductors.

4. Ungrounded conductors of voltage transformer secondary circuits shall be fused. Fuses shall be of the dual element, cartridge type, rated 20 amperes, 250 volts, mounted in barrier-type, porcelain base fuse holders.

5. Current transformers for indication and metering shall be of the window-type, with the ratio and accuracy class as shown on the Contract Drawings, rated 600 volts, minimum, and designed to withstand full wave impulse test of 10kV. The primary circuit bus bar shall be located at the center of the current transformer window, firmly supported, and fully insulated for 15 kV. The installation of current transformers shall withstand the dielectric and impulse tests specified for high voltage section.

6. Frames and cases of the current and voltage transformers, the secondaries of the current transformers, and the common secondary conductor of the voltage transformers shall be grounded to the equipment ground bus. Grounding of the voltage transformers and the carriage to the ground bus shall be made with an extra flexible grounding cable. All grounding conductors shall be made as short as possible, not grouped with other conductors, and shall be No. 6 AWG wire or larger. Ground wires shall be continuous without splices or intermediate connections. The current transformer ground wire shall be separate from the voltage transformer ground wire. The case ground wires shall be separate from the ground connections to the instrument transformer secondary wiring.

C. Detail of Equipment

1. Each fused load break switch section for supply from the Authority's distribution system shall consist of the following:

   a. One - Fused 15kV 600-ampere air interrupter switch unit with key interlock with the secondary main circuit breaker, and upstream load equipment.
   b. Three - Installed indoor type power fuses, general purpose, current limiting type, with ratings as determined by the contractor's coordination study.

   c. Three - Spare fuses, as listed in item b. above.

   d. Three - Flexible cable connections to close-coupled transformer primary terminals through porcelain enclosure bushings, with plastic supports.

   e. Six - Cable mounted neon glow tubes, with antennae, mounted on incoming cables.

   f. One - Set, Kirk key interlocks, as shown on contract drawings.

   g. Eight - 1-inch diameter ground ball studs, one per phase, line and load side of switch bus, two mounted to ground buss.

   h. One - Lot, ground buss, front and rear of enclosure sections, min. 1/4" x 2" each connected to the other.

   i. One - Lot, nameplates for all units.

   j. One - Thermostatically controlled space heater (120V 250W) with one ON-OFF switch, ammeter and blue indicating light.

   k. One – Lot, 15kV epoxy insulated bussing, while maintaining uninsulated bus clearances and spacing.

2.13 CAST COIL TRANSFORMERS

A. General

1. Dry-type fully epoxy cast coil transformers shall be equipped with a minimum of 220 degrees C, Class H insulation system for 80 degrees C rise, a high voltage (BIL) Basic Impulse Level rating of 95 kV and a low voltage BIL rating of 30 kV. The BIL rating shall be achieved without the use of lightning (surge) arresters. Hybrid insulation systems are not acceptable. Primary insulation class shall be 15 kV. Secondary insulation class shall be 1.2 kV.

2. Where dual ratings are shown, the lower rating shall be AA, and the higher rating shall be FA rating.

3. Where cooling fans are used, a test switch shall be provided to manually test fans at any time.

4. Transformer temperature controller shall be equipped with three (3) high accuracy thermal type temperature sensors. The controller shall also have control sequencing to operate cooling fans (if used) and to alarm temperature sensors. First level of alarm/control shall automatically turn fans on and off. The second level shall energize an audible alarm and send trouble alarm to the SCADA system. The third level shall cause an emergency trip of the associated secondary main breaker to drop the transformer load, send, and alarm signal to the SCADA system.

5. Specifications:

   a. Frequency of 60 hertz.
   b. Three phases.
   c. Wye winding neutral-full capacity-solidly grounded.
   d. Copper windings, primary and secondary.
   e. Fully epoxy cast coil with high temperature thermosetting varnish.
   f. Core ground strap.
   g. Provision for lifting core, coil assembly, and enclosure.
   h. Vibration-isolation pads.
   i. Hinged panels front and rear bolted with padlock hasp and staple.

6. Transformer enclosure shall consist of sheet metal enclosure with screened openings for ventilation.

7. Transformer shall conform to requirements in NEMA Standard Publication No. ST 20, ANSI/IEEE C.57.12.01/ANSI/IEEE C.57.12.10 and NEC Code as applicable.

8. The transformer shall be self-cooled and/or fan cooled, type AA or FA, ventilated dry type and shall have continuous ratings as shown on the Contract Drawings.

9. Winding insulation shall be class H rated for end temperature of 220 degrees C minimum. Average winding temperature rise by resistance from continuous operation at full load shall not exceed 80 degrees C at an ambient temperature of 40 degrees C.

10. High voltage primary windings shall be copper, three phase, 60 hertz, 13,800 volts nominal, delta connected, suitable for use on the specific voltage system on which the transformer is installed. High voltage winding insulation class shall be 15 kV, rated for basic impulse level (BIL) of 95 kV, minimum.

11. Six 2-1/2 percent no load full capacity taps shall be provided in the high voltage winding: four above and two below the rated primary voltage.

12. Low voltage winding shall be of copper, three phase, 60 hertz, 480/277 volts nominal, Wye connected, for 3 phase, 4 wire service. Low voltage insulation class shall be 1.2 kV minimum.

13. Impedance shall be in accordance with NEMA and ANSI standards.

14. Core and coil assembly shall be mounted on pads to isolate vibration from the structure. Core laminations shall be of non-aging, highly permeable, cold rolled silicon steel. The core and coil assembly shall be ruggedly constructed to prevent displacement and distortion under all normal conditions of handling and during operation under short-circuit conditions.

15. Transformer primary shall be factory connected to the load side of the interrupter switch by cable. Low voltage windings shall be factory bussed to the secondary main breaker in the low voltage distribution section. Neutral shall be fully rated and factory wired to the neutral bus bar in the distribution section. Secondary bussing shall include a length of flexible bussing, fully rated; not over 12" long located wholly within the transformer enclosure.

16. A winding hot spot temperature indicator and relay(s) with three-step temperature settings and electrically independent contacts which close with rising temperature for fan control (first step),

(second step) and tripping (third step) shall be provided. Scale shall be in degrees Celsius. Contacts shall be factory-wired to readily accessible terminal block for field connection to SCADA system and the main circuit breaker. Device 49TR and 49^{TH}.

17. Transformer shall be tested in accordance with ANSI/IEEE C57.12.91.

18. All control, SCADA and like wiring passing through or into the transformer enclosure shall be fully enclosed in metal raceways or channels, effectively grounded.

19. Provide three, 250 volt, 250-watt space heaters and ammeter, connected to 120 volts from control power bus in low voltage distribution section for each transformer. Space heaters shall be thermostatically controlled, include an on-off switch, and blue "on" indicating light and ammeter.

2.14 LOW VOLTAGE SECTION

A. 480 V System Operation

1. The unit-Substation control, protection and interlocking circuits shall be arranged for the following modes of operation of the 480-volt system:

   a. Mode selector is in "AUTO" position-supervising switch is in supervisory.

   b. Under normal mode of operation, the secondary circuit breakers of transformer No. A and No. B is closed, feeding their respective buses. The bus tie circuit breaker shall be open. Electrical interlock shall prevent closing of the bus tie circuit breaker when both secondary circuit breakers are closed.

   c. Under emergency mode of operation, the secondary circuit breaker of either transformer No. A or No. B and the bus tie circuit breaker are closed. Bus No. A and B are thus fed from a single transformer.

2. The changeover from auto mode of operation to manual mode may be selected by Auto-Manual two position selector switch provided in the switchgear. When the switch is in Auto position the control circuitry of the transformer secondary breakers and the bus tie breaker shall be arranged for the following sequences of operation:

   a. Under normal operating condition the loss of voltage on secondary of either transformer shall cause the phase sequence and undervoltage relay (Device 47) in that transformer secondary side to drop out and trip its secondary breaker through an auxiliary relay (Device 47X) providing normal voltage is available on the other bus.

   b. After tripping of one of the secondary circuit breakers, due to loss of voltage as specified above, the bus tie circuit breaker shall be closed automatically. Thus, the system is now on emergency mode of operation. The automatic closing of bus tie circuit breaker shall be prevented if the secondary circuit breaker is tripped by its overcurrent devices.

3. Return to normal mode of operation, after return of voltage to normal on the secondary of transformer which secondary breaker has tripped, shall be by performing the following operating sequence:

   a. Open the bus tie circuit breaker by its control switch (Device 1) at the switchgear.

b. Reset auxiliary relay (Device 47X).

c. Close the open secondary circuit breaker by its control switch (Device 1) at the switchgear.

4. Normally open contact of the bus tie circuit breaker shall be wired to the supervisory terminal box for providing supervisory indication of emergency mode of operation.

   a. The MBTA's Power Systems SCADA System shall be operational while the tie breaker is in manual or automatic and when the supervisor switches are in supervisory.
   b. The SCADA System control shall be able to take the switchgear from normal mode to emergency mode and return to normal mode operation whenever the supervisory switches are in supervisor.

B. Secondary Switchgear Section

1. All breakers to be insulated case type, 600V rated.

2. The two main breakers and the tiebreaker shall be electrically and manually operated and shall be interchangeable.

3. An automatic transfer operation shall be provided per Paragraph 2.15.A.

4. Spare draw-out breakers and compartments (on both sides of the tie breaker) shall be completely equipped and include all necessary electrical connections.

5. Future compartments (on both sides of the tie breaker) for future breakers shall be completely equipped for the future addition of a power circuit breaker element, including all necessary electrical connections. Insulated boots shall be furnished on all exposed bus stabs in any future breaker compartments.

6. All draw-out breakers shall have local indications with a manual reset switch for instantaneous, short time, long-time, and ground fault.

7. Provide voltmeter, and ammeter, with selector switches. These devices shall be located at each main secondary circuit breaker.

8. Provide the following safety devices for each main to be incorporated with the tie breaker transfer scheme:

   a. 27 device - undervoltage
   b. 47 device - phase sequence
   c. 49 device - transformer thermal relay
   d. 86 device - lockout relay

9. Provide terminal blocks and associated wiring for connection to the SCADA system.

10. Install a crane (overhead lifting device) or other means suitable for installing and removing all 480V draw-out breakers.

C. Low voltage section shall consist of 480-volt metal enclosed, draw-out type, indoor switchgear consisting of following units as shown on the contract drawings.

1. Transformer No. A secondary main circuit breaker and its control and instrumentation unit.

2. Bus No. A feeder breaker units.

3. Bus tie circuit breaker, its control and instrumentation unit.

4. Bus No. B feeder breaker units.

5. Transformer No. B secondary main circuit breaker and its control and instrumentation unit.

D. The low voltage section shall consist of three basic compartments from front to rear: the front breaker compartment, the center bus compartment, and the rear cable compartment. The front breaker compartment shall contain the draw-out circuit breaker elements, each mounted in its own barriered cell having a hinged door and handle with an external trip button. Active or future use cells equipped to accept circuit breakers shall be complete with the circuit breaker draw-out mechanism and all current-carrying parts. The center bus compartment shall contain the section and main bus and isolated neutral bus. Size of the rear cable compartment shall accommodate all incoming and outgoing cables required within each vertical switchboard section. This compartment shall also contain the runback, which is extended into this compartment from the bus compartment and a ground bus bolted directly to the switchgear frame. A neutral stud shall be extended into the cable compartment in each vertical section for connection of neutral conductors. Provide lugs for neutral and ground connection for each breaker and a bus connection for connecting the neutral to the ground bus with a removable isolating link.

E. Each main, bus tie and feeder circuit breaker compartments and instrument compartment shall be provided with a steel door having concealed hinges and hand operated latching device. Tools shall not be required to open or close the doors. The potential transformers and current limiting fuses shall be rigidly mounted in compartments provided with a hinged door for easy access. Each vertical section shall be provided with hinged sheet steel doors at the rear. Hinges shall be of heavy-duty type. Doors shall be provided with stops to hold them securely in the open position and provision for padlocking in open position.

F. The stationary elements of switchgear shall include copper buses, copper connections, instrument transformers, the stationary portion manually operated mechanism for moving the circuit breaker to and from the connected position, terminal blocks and wiring for control and secondary connections. The removal element of switchgear shall consist of circuit breaker, the removal portion of the disconnecting devices, the operating mechanism and mechanical interlocks. The stationary structure shall be so constructed that each circuit breaker unit shall be interchangeable with every other unit of similar rating.

G. Buses: Main bus, bus taps and run-back buses shall be of high conductivity rectangular silver-plated copper with rounded edges, mounted on supports of high impact non-tracking insulating material. Buses shall be braced to withstand maximum short circuit stresses available in the system. Buses shall be designed to carry rated current continuously without exceeding the hottest-spot temperature rise of 65 degrees C above building ambient of 40 degrees C. All bus taps and connections shall be either welded or tightly bolted with a minimum of four 1/2-1/3 bolts. Contact surfaces of bolted joints shall be silver-plated. Buses shall be provided in accordance with the following:

1. Main bus shall be 3 phase, 4 wire, having a continuous current rating not less than the full load current (FA rating) of the transformer to which it is connected with a 100 percent rated neutral insulated from the structure.
2. Vertical riser buses shall extend from main bus to bus side terminals of feeder circuit breakers. Riser buses shall be properly sized for the breakers connected.

3. Buses shall be phased 1-2-3 left-to-right, top-to-bottom and front-to-rear, as viewed from the front of unit-substation.

4. Run-back buses from feeder breaker load terminals shall be extended through the isolating barrier to the cable compartment. Similar provisions shall be made for spaces equipped for future circuit breakers.

5. Insulating barrier: An insulated, removable barrier shall be provided to isolate the main and riser buses from the cable compartment.

H. Main and bus tie circuit breaker shall be three- pole, draw-out type power circuit breaker with solid state programmer conforming to ANSI C37.13, C37.16 and C37.17 having the following ratings and accessories.

1. Ratings:

Rated voltage	:	600 V
Frame size	:	main bus rating-as shown on the drawings
Current Sensor Rating	:	main bus rating-as shown on the drawings
Rating plug	:	as shown on the drawings
Current setting	:	Adjustable (Multiple of Rating smooth steps plug Amps) between 0.5 to 1.1

2. Operating mechanism: Stored energy type, suitable for operation from a 120 volt ac supply and shall be electrically and mechanically trip free. Operating circuits shall successfully close the breaker over a voltage range of 90 to 130 volts and trip the breaker over a voltage range of 70 to 140 volts. The breaker shall be designed so that they may be tripped manually in an emergency. A removable handle shall be provided for manual closing of the breaker for maintenance and adjustment. Control circuit shall be arranged to make the mechanism non-pumping, and shall have coils suitable for continuous operation. Closing relays shall be such that they may be used with either a momentary or maintained contact control station. Provisions shall be made for manually closing and tripping the breaker by mechanical means.

3. Disconnecting devices: Circuit breaker shall be equipped with the main and secondary circuit disconnecting devices to make the breaker and operating mechanism a removable element. The primary disconnecting devices consist of self-aligned assemblies. Contacts shall be constructed of high quality material designed to insure high-pressure contact guaranteed not to distort or fail under mechanical stresses and heating due to duties specified for circuit breakers. All contact surfaces shall be heavily silver-plated. The secondary disconnecting devices shall provide connections for the control circuits and interlocks between the removable element and the housing. The devices shall be accurately located and securely mounted to maintain alignment.

4. Draw-out mechanism: Designed to move the breaker removable element from disconnected to test and connected position and shall overcome the mechanical resistance of making and breaking the contacts of the disconnecting devices. Positive mechanical interlocks shall be provided on the circuit breaker to prevent the withdrawal of the removable element when the breaker is in the closed position and to prevent the insertion of closed breaker from the test to the operating position. The interlocks shall also discharge the spring of the stored energy operating mechanisms before the breaker removable element can be fully withdrawn from its housing. Mechanism shall be arranged to permit the breaker to be racked from "connected" to "test" to "disconnected" position with the door closed. A positive

stop shall be provided to prevent over-travel of the removable element when moving into the operating position. A similar stop shall be provided for the test position.

5. Series trip device: Solid state type, equipped, as a minimum, with adjustable long-time pickup (set at 1.0 of current setting) and time delay; short-time pickup and time delay; adjustable instantaneous pickup; adjustable ground fault pickup and time delay functions including neutral transformer for three phase, four wire, grounded system.

   The trip unit shall also display the following at the trip unit:

   - Phase currents
   - Ground currents
   - Energy (MWH)
   - Peak Demand (MW)
   - Present Demand (MW)
   - Trip Settings
   - Power Factor
   - Phase Voltages

6. A mechanical indicator shall be provided to show whether the breaker is in the open or closed position. The indicator shall be visible from outside the compartment with the compartment door closed and latched.

7. Target indicator shall be provided to indicate the tripping mode - long time, short time, instantaneous overcurrents and ground fault.

8. In addition to auxiliary switches required for control, interlock, indication and alarm circuits, each circuit breaker shall be furnished with a minimum of four "a" and four "b" spare auxiliary switch contacts, wired to outgoing wiring terminal block for Authority's use. The contacts shall be easily convertible in field.

9. All auxiliary switches, whether cell mounted or mounted on removable element, and breaker control circuit wiring connected through secondary disconnecting devices shall be made up and operable when breaker is racked to the test position so that the breaker may be closed and tripped electrically or mechanically with primary disconnecting devices open.

10. Normally closed auxiliary switches mounted on removable elements and used for interlocking shall be shunted with carriage-operated cell switches to permit operation of interlocked equipment when breaker is in the withdrawn or test position.

11. Breakers to be equipped to work with the MBTA's Power Systems SCADA System, open and closed indication.

I. Feeder circuit breakers shall be three-pole draw-out type power circuit breakers with solid state programmer conforming to ANSI C37.13, C37.16 and C37.17 having the following ratings and accessories.

1. Ratings

Rated voltage	:	600 V
Frame size	:	per contract drawings

Current Sensor Rating	:	per contract drawings
Rating plug	:	per contract drawings
Current setting	:	adjustable (Multiple of Rating smooth steps plug Amps) between 0.5 to 1.1

2. The breakers shall be manually operated. Feeder breakers shall have open/closed indication at the SCADA system, but no SCADA system control. All other applicable requirements specified for main and bus tie breakers specified above are applicable for the branch breakers as well.

J. Instrument Transformers

1. Instrument transformers shall be of the dry type. Current transformers shall have 5-ampere secondaries. Rating of the instrument transformers shall be as specified herein. Potential transformers shall be rated 480/120 volts. Suitable current limiting fuses shall be provided for the primaries and non-renewable cartridge type fuses for the secondaries. A total of six spare current limiting fuses and 12 spare cartridge type fuses shall be furnished.

2. Potential transformers equipped with current limiting primary fuses shall be mounted on draw-out or tiltout carriage. Design the front of the carriage to close the section when the transformers are in the operating position. Design primary contacts for the draw-out feature to ensure continuous positive contact pressure. Furnish carriages of sufficiently rigid design to maintain proper alignment of the primary contacts. Provide visible grounding devices to make certain that the draw-out carriage mounted potential transformer primary terminals are grounded when the carriage is withdrawn.

3. Fuse all ungrounded conductors of potential transformer secondary circuits. Provide fuses of the dual element cartridge type rated 20 amperes, 250 volts, mounted in barrier type porcelain base fuse holders. All instrument wiring to be copper fully insulated.

4. Ground the frames and cases of the potential transformers. The common secondary conductor of the potential transformers shall be grounded to the switchgear ground bus. Make the grounding of the potential transformers and the carriage to the switchgear ground bus by means of an extra flexible-grounding strap. Make all grounding conductors as short as possible. Use continuous ground wires without splices or intermediate connections. Install the case ground wires separate from the ground connections to the instrument transformer secondary wiring.

K. A two wire, grounded, alternating current, 120 volt, minimum No. 6 AWG control bus shall be provided throughout switchgear lineup insulated for 600 volt ac service. Supply shall be wired to suitable screw type terminal blocks located in the bus tie breaker vertical section for connection of AC supply cables entering from the top. Each breaker control circuit shall be supplied from this ac bus through fusible pullout disconnects with cartridge type fuses suitably rated and located in each compartment. In addition, each circuit breaker close circuit shall be provided with a secondary set of fuses to prevent blowing of main fuses (and loss of trip ability) on closing faults. The fuse holders and fuses shall be rated 250 volts. All necessary fuses shall be furnished with the equipment. In addition, a minimum of 10 percent (but not less than two) spare fuses of each rating shall be furnished.

L. Each separated vertical section within a switchgear lineup shall be provided with an electric strip heater of adequate size to prevent condensation within the section. All heaters installed in the switchgear shall be monitored by means of an ammeter scaled for the heater load. Heater shall be provided with properly designed guards to protect operating personnel with accidental contact with hot surfaces. Space heater circuits shall be wired to terminal block for connection to control power transformer.

M. All other devices required listed and/or shown on the Contract Drawings or required to achieve intended operation as specified shall conform to requirements if specified in this Section or to the best industry practice.

2.15 DETAIL OF EQUIPMENT

A. Secondary Main Circuit Breaker and Instrument and Control Unit

One vertical switchgear unit equipped with bus and taps arranged for connection to incoming bus for phase and neutral entering from the transformer section.

One circuit breaker compartment equipped with the following:

- One 600-volt draw-out circuit breaker rated as shown on contract drawings.
- Three current transformers, suitable ratio for indication, ANSI accuracy class C200.
- One set of control and power disconnect devices and fuses.

One instrument compartment equipped with:

- Two interposing relays, to close and trip the circuit breaker via supervisory, (Devices 201C and 201T).
- One control switch "TRIP-CLOSE" for closing and tripping the main circuit breaker in the operating and test positions, with green, white and red indicating lights (Device 1).
- One phase sequence and undervoltage relay.
- One multi-contact auxiliary relay for automatic transfer scheme, hand reset type, 125 volt (Device 47X).
- Two potential transformers, 480/120 volts, with primary current limiting fuses connected to line side of circuit breaker, open delta primary, grounded open delta secondary. Secondary also wired to terminal for external wiring.
- One indicating voltmeter, transformer rated, 0-750 volt scale.
- One voltmeter switch, 7-position "AN-BN-CN-OFF-AB-BC-CA".
- One indicating ammeter, transformer rated, 0-CT ratio ampere scale.
- One ammeter transfer switch, 4-position, "OFF-A-B-C", center-of-circuit type.
- Lockout relay, manually reset type.
- One on-off switch and heater ammeter with blue indicating light for space heater.
- One circuit breaker control mode selector switch "Local-Off-Supv" (Device 43).

B. Bus Tie Circuit Breaker and Instrument and Control Unit.

- One vertical switchgear unit equipped with buses and taps for bus tie circuit breaker entering from the bus on the left and right of the unit. Also equipped with space heater and guard.

- One circuit breaker compartment equipped with the following:

- One 600-volt draw-out air circuit breaker rated as shown on the contract drawings.

- One set of control and power disconnect devices with fuses.

- One instrumentation compartment, equipped with the following:

- One control switch, "TRIP/CLOSE" for closing and tripping the tie circuit breaker in the operating and test positions, with green and red indicating lights (Device 1).

- One circuit breaker control mode selector switch "LOCAL-OFF-SUPV" (Device 43).

- One two position selector switch for selection of mode of operation of 600 volt system -- automatic or manual, AUTO-MANUAL.

- Two interposing relays, to close and trip the circuit breaker via supervisory.

- One on-off switch and heater ammeter with blue indicating light for space heaters.
- One set of auxiliary power disconnect devices with fuses for 120-volt control power bus.

C. Branch Circuit Breaker Unit consisting of the following:

- One vertical switchgear unit equipped with main bus of same size as the main or bus tie breaker to which it is attached and appropriately sized bus taps to breakers and runback buses with cable lugs from each branch circuit breaker.

- Individual compartments with hinged doors for branch circuit breakers. Breakers shall be draw-out air circuit breakers with rating sensors and rating plugs of sizes as shown on the Contract Drawings. Number of compartments as shown on the drawings.

- One on-off switch and heater ammeter with blue indicating light for space heater.

- One set of power and control disconnect devices with fuses.

- One control switch TRIP/CLOSE for closing and tripping the circuit breaker in the operating and test positions, with green and red indicating lights.

D. Bus transition unit forming vertical unit of the switchgear.

2.16 AUTOMATIC TRANSFER OPERATION OF BUS TIE

A. Basic Breaker Control and Interlocking Operation

1. The control circuits of secondary and tie circuit breakers in the 480-volt switchgear shall be arranged for both local control and remote control via the Authority's SCADA system.

2. Three- three-position (SOURCE 1-OFF-SOURCE 2) control mode selector switch (Device 43) for

transferring each (2 secondary main and one bus tie) circuit breaker from local control to supervisory or supervisory to local control shall be provided. In addition to the contact required for the control circuit transfer, the switch shall be provided with a contact (closed in the "SOURCE 2," open in the "SOURCE 1" position of the switch) for remote switch position indication via Authority's supervisory system. Each of these three breakers shall also be provided with control switch (Device 1).

3. All control switches (Device 1) located at the switchgear shall be provided with green, white and red indicating lights, mounted above the switch (green at left, red at right). The red light shall be connected in series with "a" contact of the breaker and breaker trip coil to indicate breaker closed position and to monitor the breaker trip circuit. The white indicating light shall indicate the mechanism charged condition. The control switches shall be provided with slip contacts so arranged that the manual trip of the breaker shall not actuate the circuit breaker auto-trip alarm. Similarly, the auto-trip alarm shall not be actuated if the circuit breaker is tripped via the supervisory system.

4. The control switch (Device 1) and indicating lights of 480 volt secondary circuit breakers and bus tie circuit breaker shall be provided in front of breaker it controls to close and trip the breaker when the removable unit is in the "operating" or "test" position. Control mode selector switch (Device 43) that is common to all the three circuit breakers shall be provided in front of the bus tie circuit breaker for selecting the mode of operation of circuit breakers in the "operating" position. Any circuit in the "test" position could be operated only from its control switch (Device 1) in front of the circuit breaker.

5. Control circuits shall be arranged to provide the following scheme of operation:

   a. With the control mode selector switch (Device 43) in the "SOURCE 2" position, local closing functions shall be disabled and the circuit breaker can be closed only via the Authority's supervisory system and only when the breaker removable element is in the "operating" position.

   b. The circuit breaker can be tripped either via the supervisory system when the circuit breaker removable element is in the "operating" position only or by the control switch at the switchgear in both "operating" and "test" positions of breaker removable element.

   c. With the control mode selector switch (Device 43) in the "SOURCE 1" position, all supervisory functions shall be disabled.

   d. Each of the three circuit breakers, two secondary circuit breakers and one bus tie circuit breaker, can be closed or tripped from the control switch at the switchgear in both the "operating" and "test" positions.

   e. With the control mode selector switch (Device 43) in the "OFF" position, all SOURCE 1 and SOURCE 2 control functions shall be disabled, except the tripping function of the control switch at the switchgear.

6. Control mode selector switch (Device 43) shall be mounted directly above the breaker control switch (Device 1) of the bus tie circuit breaker.

7. The protective device and relay circuitry of the breakers shall not be affected by the control mode selector switch (Device 43); when actuated these devices shall trip the respective breakers regardless of the position of the selector switch (Device 43).

8. The 480-volt ac switchgear is normally operated with the bus tie circuit breaker between the two sections open. Electrical interlock shall be provided to achieve the following mode of operation:

a. Allow closing of any two of the three circuit breakers at any one time.

b. Prevent closing of the other secondary circuit breaker when one of the secondary circuit breaker and tie circuit breaker are closed.

9. Automatic tripping and lockout of secondary circuit breaker for actuation of transformer protective devices.

10. Automatic bus transfer scheme for low voltage switchgear in the event of loss of voltage on the secondary of any one of the transformers.

B. Provide for automatic transfer Device No. 83 of the main and bus tie circuit breaker as follows:

1. Normal Operation

a. Both main circuit breakers closed.

b. Bus tie circuit breaker open.

2. Loss of voltage of either 480 volt bus:

a. Open transition sequencing shall be implemented.

b. An undervoltage relay Device No. 27 shall operate initiating local annunciation and simultaneously energizing a time delay relay Device No. 2.

c. After an adjustable (0-10 sec) time delay set at 5 (five) seconds, and if voltage is present at opposite end, tripping of main circuit breaker and automatic closing of the tie circuit breaker shall result.

3. Interlocks

a. Prevent closing of tie circuit breaker into a faulted bus either phase to phase, line to neutral and/or line to ground or unless one main circuit breaker is open.
b. Trip the tie circuit breaker whenever both main circuit breakers are closed.

c. A 43 (auto-manual) device shall be installed at tie breaker location to select automatic or manual transfer. This switch position shall be monitored by SCADA.
d. The 43 (supervisory) devices shall be installed at main breaker and the breaker location to select "SOURCE 2", "Off", and "SOURCE 1" control. This switch position shall be monitored by SCADA and be independent of the supervisory 43 device.

4. Phase Indication

a. A phase sequence voltage relay, Device No. 47, shall indicate correct phase sequence between the 480-volt secondaries of Line 1 and Line 2.

b. A single-phase synchronism check relay, Device No. 25, shall indicate correct phase synchronism between Phase A and Line 1 and Phase A or Line 2. The relay shall work in conjunction with the phase sequence voltage relay to provide a single indication through the supervisory system that the two 480 volt lines are in synchronism for all three phases.

2.17 LIFTING DEVICE AND MOBILE TRANSFER TRUCK

A. A structure mounted circuit breaker lifting device and a mobile portable transfer truck to raise, lower and transfer the circuit breakers shall be provided for each double-ended unit substation.

B. The device shall be capable of removing and inserting breakers from any position in a vertical stack with complete ease and safety.

C. The lifting mechanism shall be mounted permanently on the unit substation structure.

2.18 CIRCUIT BREAKER TEST CABINET

A. Contractor shall provide a wall mounted test cabinet for electrical operation of circuit breakers at location remote from the switchgear. The test cabinet shall include a control switch, or a set of pushbuttons, to close and trip the breaker, position indicating lights, ten feet of control cable with a connector at the end for connection to the breaker, a set of properly sized fuses to protect the control circuit and screw type terminals for No. 8 AWG conductors of 125 volt control supply.

B. Provide a worktable for bench testing and maintaining the draw-out circuit breakers using the circuit breaker tester and other equipment.

2.19 ACCESSORIES

A. Provide a minimum of two (2) gray lockable galvanized steel storage cabinets for storage of accessories and spare parts for each unit substation.

B. Tools and Accessories: Following accessories shall be provided and shipped with each unit substation:

1. A set of all tools required for the erection, operation and maintenance of all equipment.
2. A removable hand crank for moving the circuit breakers to operating position (if required).
3. A set of special wrenches for the primary disconnecting devices of the circuit breaker and other special purposes.
4. A portable test set for testing the solid state protective devices during installation and maintenance.
5. One set of fuse pullers.
6. All spare fuses as listed in previous sections, high and low voltage.
7. One pair 25 kV rubber lined, leather, insulated lineman gloves.
8. One full length coat, with hood.
9. One neon voltage detector on telescoping pole, detex by Biddle Co. or approved equal.
10. One Analog phasing tester, detex by Biddle Co. or approved equal.
11. Solid state trip unit test kit, capable of testing all trip functions, powered by 120 volts ac.

12. Installation, operation and maintenance manuals and as-built factory drawings.

13. Laptop computer for programming meters and SCADA equipment.

14. Hand-held label maker/printer: Provide Panduit LS3, hand-held printers/labeler with case, LS3 case and 10 rolls of marker labels, LW-2.

15. Raychem Rayflate Seal Duct System:

    a. Inflation tool with pressure gauge and connectors: Raychem RDSS - 1G - SR AS.

    b. Portable air tank with 6-foot hose for use with inflation tool.

        1. Tank size: 14 gallons
        2. Dimensions: Length: 26-inches
           Height: 14-inches
           Diameter: 12-inches

    c. Portable inflation tool (requires carbon dioxide-CO_2 cylinders): Raychem RDSS - IT - 16

    d. One box of carbon dioxide CO_2 gas cylinders: Raychem E7512 - 0160.

    e. Fifty Rayflate 5-inch bags: Raychem RDSS - 125.

2.20 SPARE CIRCUIT BREAKERS

A. Contractor shall provide a spare circuit breaker of the largest frame size per bus section, which is interchangeable with the circuit breakers being provided with the switchgear.

2.21 SUPERVISORY CONTROL

A. The equipment furnished under these specifications shall include control and indication circuits wired to terminal blocks for the supervisory control and indication functions specified herein. All auxiliary contacts provided for indication circuits shall have a minimum rating of five amps at 125 volts dc and ac continuous. Refer to Specification Section 16313 for Remote Terminal Units.

B. Supervisory Control and Indication Operating Philosophy

1. The Authority shall provide a computerized supervisory system for remote control of circuit breakers in various stations in MBTA network and monitoring of equipment and auxiliary circuits in substations. The master station and the computer equipment of the supervisory system shall be located at the Authority's Operations Center. A remote terminal equipment cabinet shall be provided at the location specified under this Section shall be located.

2. The Contractor shall furnish, install and connect all interposing relays (Device 201C, 201T) for proper interfacing of the breaker control circuits with the Authority's supervisory equipment, and provide a normally open contact from each supervisory-controlled circuit breaker for remote breaker contact position indication. Contractor shall also provide all contacts, relays and devices necessary or remote monitoring of below listed equipment and circuits. The interposing relays shall be supplied from the 125-volt control bus of the switchgear through a set of fuses. The load side of positive fuse, one side of the interposing relay coil and all supervised contact devices shall be wired to outgoing wiring

terminal blocks at switchgear. These circuits shall be extended to a terminal box near the supervisory equipment cabinet.

3. The wiring between the unit-substations and supervisory terminal box and between the supervisory terminal box and SCADA RTU shall be furnished and installed by the Contractor.

4. The furnishing and installation of supervisory interface terminal box and SCADA remote terminal unit (RTU) is not included under this Section. The following circuit breakers at the substation shall be provided with devices for remote close- trip control and indication via Authority's supervisory system:

   a. Main secondary circuit breakers

   b. Bus-tie circuit breakers

5. The following circuits and devices included under this Section shall be provided with monitoring contacts for remote indication via Authority's supervisory system.

   a. Position of control mode selector switch of supervisory controlled breakers (Device 43) and AUTO-MANUAL Selector Switch for 480 volts automatic transfer scheme.

   b. Lockout relay (Device 86), of secondary breakers.

   c. Substation transformer winding hot spot temperature indicator (Device 49T), one for each transformer.

   d. Emergency mode of operation.

   If the transformer protective device specified above cannot be provided with required number of independent contacts for local annunciation, supervisory indication and trip functions, Contractor may provide multiplying relay(s) as required. The contacts of the protective devices shall be first wired to multiplying relays, and independent contacts of multiplying relays shall be utilized for the various functions specified.

C. SCADA System

1. Provide SCADA indications (open and close) for all breakers in the switchgear.

2. Provide SCADA control (close and trip) for the main and tie circuit breakers.

3. Provide SCADA indication for loss of control power and loss of 13.8 kV voltage on either side of the switchgear.

4. Provide 43 switch devices for the main secondary circuit breakers and the tie breaker. These switches are two position switches that selects "supervisory on" and "local" control. These switch positions shall be monitored by SCADA.

5. Wiring for the SCADA system use form C relays and form C wiring (three-wire method). The minimum size wire shall be #12's, use SIS wire inside the switchgear and XHHW in a minimum of 1" rigid galvanized conduit from the switchboard to SCADA interface panel.

D. SCADA System Points

1. The following SCADA control points shall be provided for each section of the unit substation as a minimum: (Note: Substitute "3" for "1" and "4" for "2" where appropriate)

	Description	Device Number
a.	Main secondary breaker - line 1: close	152-MSB1C
b.	Main secondary breaker - line 1: trip	152-MSB1T
c.	Main secondary breaker - line 2: close	152-MSB2C
d.	Main secondary breaker - line 2: trip	152-MSB2T
e.	Bus tie breaker: close	152-MSBTC
f.	Bus tie breaker: trip	152-MSBTT

2. The following SCADA indication points shall be provided for each section of the unit substation as a minimum: (Note: Substitute "3" for "1" and "4" for "2" where appropriate)

	Description	Device Number
a.	Load break switch - line 1: open/closed	89-1
b.	Load break switch - line 2: open/closed	89-2
c.	Loss of 13.8 kV power - line 1: alive/dead	47-MSB1
d.	Loss of 13.8 kV power - line 2: alive/dead	47-MSB2
e.	Transformer - line 1	
	Temperature alarm: Temp setting	
	Per manufacturer's spec.	49T-1A
	Temperature trip: Temp trip	
	Per manufacturer's spec.	49T-1T
f.	Transformer - line 2	
	Temperature alarm: Temp setting	
	Per manufacturer's spec.	49T-2A
	Temperature trip: Temp trip	
	Per manufacturer's spec.	49T-2T
g.	Loss of control power	
	83-position switch: normal/alternate	83-CP
	27 Loss of power: alive/dead	27-LOCP
h.	Main secondary breaker - line 1: open/closed	152-MSB1
i.	Main secondary breaker - line 2: open/closed	152-MSB2
j.	Bus tie breaker: open/closed	152-MSBT
k.	43 device switch position:	
	Main breaker - line 1: supv-off-local	43-MSB1
	Main breaker - line 2: supv-off-local	43-MSB2
	Tie breaker: SOURCE A/SOURCE B	43-MSBT
	Tie breaker transfer scheme: auto/ manual	43MSBTA/M
l.	All feeder breakers: open/closed	152-FDR#
m.	Overcurrent temperature switch	
	Main secondary breaker 1	152-1/OTS
	Main secondary breaker 2	152-2/OTS
	Tie breaker	152-T/OTS

3. See contract documents (SCADA Drawings) for additional SCADA indication points, analog points, and devices needed for other associated equipment.

PART 3 - EXECUTION

3.01 GENERAL

A. Install, wire and connect unit substations complete and ready for operation in accordance with these Specifications, the manufacturer's instructions, and as shown on the Contract Drawings.

3.02 DELIVERY, STORAGE AND HANDLING

A. Equipment and materials shall be delivered to the site in original containers, suitably sheltered from the elements, but readily accessible for inspection by the Engineer until installed. All items prone to moisture damage, such as controls and electrical apparatus, shall be stored in dry, heated spaces. Equipment and materials shall be tightly covered and protected against dirt, water, chemical and mechanical injury and theft. Damage or defects, which occur before acceptance of the work, shall be repaired or replaced as directed, without additional cost to the Authority.

B. Ship the unit-substation in assembled sections of maximum size taking into consideration available access for each switchgear as shown on the Contract Drawings.

C. Temporary Bracing: Brace and package each section to permit hoisting, lowering, and skidding into position. Clearly, label and temporary internal bracing of each section as TEMPORARY BRACING: TO BE REMOVED BEFORE OPERATION.

D. Protection Against Concealed Damage. Package equipment, which may be subject to non-visible damage during shipment with mechanical impact recorders which, shall register the maximum acceleration to which the equipment has been subjected along each axis. Unpack such equipment in the presence of the Engineer.

3.03 CONDUIT AND WIRING WORK

A. Section 16050 Basic Materials and Methods for Electrical Work of the MBTA Standard Specifications-Construction and Special Provisions shall apply.

3.04 GROUNDING

A. Section 16450 Grounding of the MBTA Standard. Specifications-Construction and Special Provisions shall apply.

3.05 DOUBLE-ENDED SUBSTATION INSTALLATION

A. Install switchgear in the locations as shown on the Contract Drawings, secure, plumb and level and in true alignment with related adjoining work.

B. Provide anchor bolts and anchorage items and field check to insure proper alignment and location. Provide templates, layout drawings, and supervision at the job-site to insure correct placing of anchorage items in concrete. Check embedded items for correctness of location and detail before concrete is placed.

C. Provide supporting members, fastenings, framing, hangers, bracing, brackets, straps, bolts, angles, as required to set and rigidly connect the work.

D. Provide temporary bracing, guys, or other devices as required to accomplish erection and to provide safety and stability until all work is in final position completed and approved.

E. Control erection tolerance requirements so as not to impair the strength, safety, serviceability, or appearance as approved by the Engineer.

F. Exercise special care during construction to avoid overloading any part of the structure. Repair or replace any item damaged due to overloading to the satisfaction of the Engineer, at no additional cost to the Authority.

G. Align mismatched holes by reaming or replacing of clip connectors. Cutting with torches shall not be permitted.

H. The Contractor shall furnish, install and connect 480/277 volt power cables between the substation and the building distribution panel; Kirk-key interlock between the substation and the 13.8 kV switchgear; control, relaying and interlocking circuit cables; grounding cables; and all other wiring necessary for intended operation of the unit substation as specified herein and as shown on Contract Drawings.

I. After completion of switchgear installation, the Contractor shall verify that all doors and the draw-out fuse and PT carriages operate freely and the breaker removable elements can be moved into and removed from the housings. Contractor shall correct all misalignments to the satisfaction of the Engineer. Contractor shall verify that all mechanical safety interlocks are operating properly. The completed installation shall be tested and checked out in accordance with an approved procedure.

3.06 TESTS

A. General

1. All equipment to be furnished and installed shall be subject to the following test program. Testing shall include tests at a manufacturer's facility and in the field.

2. The Contractor shall formulate overall test program of the equipment which shall include but not be limited to the test specified in this Section to ensure equipment compliance with the relevant standards, this Specification and satisfactory and reliable performance in intended operation.

3. Tests at the factory shall include, but not be limited to:

   a. Manufacturer's standard tests.

   b. Field-tests as listed in Section 16950

   c. Factory Tests as per relevant NEMA, IEEE and ANSI Standards not included in Article 3.06.C.

   d. Any other tests to ensure satisfactory performance of equipment.

4. Tests in the field shall include, but not be limited to:

   a. Tests as listed in Section 16950.

   b. Tests as per relevant NEMA, IEEE and ANSI Standards not included in Article 3.06.D, this Section.

c. Any other tests to ensure satisfactory performance of equipment.

5. The Contractor shall meet the requirements in this Section, for testing and shall furnish test reports as specified in this Section for obtaining clearance for packing and shipment of equipment tested.

B. Conditions for Tests

1. General Conditions:

Prior to testing of any equipment specified in this Section, all of the following conditions shall be fulfilled by the Contractor:

a. Contractor has made the "For Record" submittal of shop drawings of the equipment scheduled for testing to the Engineer. Note that "For Record" submittal shall be made only after the Engineer has approved the equipment.

b. The Engineer has approved the Contractor-prepared test procedure.

c. A minimum of four weeks advance notification shall be given to Engineer and Authority on the scheduled date of tests to enable them to witness the same.

2. Witnessing Tests:

a. Engineer shall witness complete testing of all equipment unless a waiver is granted, in which case test reports of equipment for which waiver was granted, shall be submitted for review to obtain clearance for packing and shipping. Waiver of witnessing tests on any one equipment shall not be construed as a waiver for all remaining equipment either of the same type or of different type.

3. Responsibility

a. The Contractor shall assume full responsibility during the factory and field testing of all equipment and installation provided by him. Should there be any loss or damage to such equipment, materials or the building as result of these tests, the Contractor shall be fully responsible for replacing the damaged equipment and repairing the building. Replacement of damaged equipment shall include all costs, including, but not limited to, transportation of, and installation of replacement equipment.

4. Rejection and Retesting

a. Failure of equipment to withstand tests or to meet ratings shall be sufficient grounds for rejection of equipment.

b. Any equipment rejected shall be retested in presence of the Engineer, or his representative, after rectification. If the modifications or changes are such as to affect any of the drawings, diagrams or any other documents submitted and accepted by the Engineer, revised drawings or diagrams shall be submitted, showing proposed changes and Engineer's approval obtained before changes or modifications are made on the equipment. Modification or changes, which do not warrant revision of any drawing, shall be furnished to the Engineer along with notice of retesting.

c. If it is not possible to rectify rejected equipment, new equipment shall be manufactured and the

requirements of the drawings and design calculations of the original unit shall be applicable for the new unit.

5. Cost of Rectification or New Unit

   a. The entire cost of rectification or new unit shall be borne by the Contractor including retesting and cost of witnessing retesting.

6. Cost of Tests

   a. The price for conducting all factory and field tests and checkouts in presence of the Engineer, or his representative, including entire cost of rectification, retesting and supplying new unit(s), shall be deemed included in the Contract Price. The expenses related to travel, lodging and boarding for the Engineer and/or his representative for witnessing of tests shall, however, be borne by the Authority at no expense to the Contractor, except when retesting is required. In the latter case, all expenses for travel, lodging, meals and hourly payroll costs including overhead and fringe benefits for the Engineer and/or his representative shall be borne by the Contractor as directed by the Authority.

C. Factory Tests

1. Double-ended Unit Substation Assembly

   a. Following tests listed in ANSI C37.20, as "Production" test shall be conducted at the manufacturer's facility on the Double-ended Unit Substation assembly.

      1) Power frequency dielectric tests
      2) Mechanical operation tests
      3) Grounding of instrument transformer cases test
      4) Electrical operation and control wiring tests

         - Control wiring continuity test
         - Control wiring insulation test
         - Sequence tests
         - Polarity tests

   b. Contractor shall submit copies of "Design Tests" report conducted on similar assembly.

2. 13.8 kV Section

   a. Metering circuit functional and polarity checks.

   b. Door alignment and breaker interchangeability check.

   c. High potential test of primary and secondary circuits.

   d. Switch mechanism and manual operation inspection checks.

   e. Switch pole resistivity measurements.

3. Air Interrupter Switches

a. The manufacturer shall submit the certificate of design tests conducted on an identical air interrupter switch for Engineer's approval.

b. The manufacturer's standard production tests shall be conducted in the presence of the Engineer.

4. Dry Type Transformers

a. Following tests shall be conducted at the manufacturer's facility on each transformer. These tests shall be conducted as described in ANSI C57.12.91 and/or ANSI C57.12.01.

1) Induced potential tests.
2) Applied potential tests.
3) Resistance measurements of all windings on the rated voltage connections of each unit and at the tap extremes of one unit of a given rating on an order.
4) Ratio tests on the rated voltage connection and on all tap connections.
5) Polarity and phase-relation tests on the rated voltage connection.
6) No-load loss at rated voltage connection.
7) Exciting current at rated voltage on the rated voltage connection.
8) Impedance and load loss at rated current on the rated voltage connection of each unit and on the tap extremes of one unit of a given rating on an order.
9) BIL (Impulse) Test.

b. In addition, manufacturer's test certificates for the following tests specified as optional tests in ANSI C57.12.01 and/or ANSI C57.12.91 and/or NEMA ST20 conducted on a similar transformer shall be furnished:

1) Temperature tests
2) Impulse tests
3) Insulation power factor tests
4) Short circuit test

5. Power Circuit Breakers

Following tests listed in ANSI C37.50, as "Production Tests" shall be conducted at the manufacturer's facility on each 600-volt power circuit breaker to be furnished in this Contract.

Calibrated tests:

- Direct acting trip devices
- Undervoltage trip devices

Control, secondary wiring and devices check
Ac dielectric-withstand test
No-load operation test
All manufacturers' standard tests, which are not, covered in the above listed production tests.

In addition, manufacturer shall furnish test certificates for all the tests listed in ANSI C37.50 as "Design Tests" conducted on similar 600-volt power circuit breaker.

6. Relays

a. Following tests as listed in ANSI C37.90 shall be conducted on all the relays.

1) Test for operation at minimum voltage.
2) Dielectric tests.

7. Auxiliary Equipment and Components

a. Tests on auxiliary equipment and components shall be conducted as required by relevant ANSI, IEEE, NEMA and UL Standards in accordance with the manufacturer's standard testing procedures.

D. Field Tests

1. General

a. Contractor shall perform the field tests on all equipment specified in Section 16950 after installation of the equipment. Field tests are to be performed to supplement the factory tests and to verify proper operation of equipment and proper calibration and coordination of protective devices. Contractor shall retain an independent testing contractor to furnish, set up and operate all special equipment required for these tests.

b. The work includes furnishing of labor, material, test instruments and services necessary to perform required testing and checking of electrical equipment and installation.

c. All tests shall be successfully completed to show that the installation meets the specification requirements and that the equipment and devices operate as intended, before final acceptance by the Authority.

d. Tests and checkouts shall be conducted in accordance with the Engineer's approved test procedure specified herein and in National Electrical Code, Massachusetts State Electrical Code and applicable Standards and Specifications of ANSI, NEMA, NETA, ICEA, AEIC, etc.

e. Contractor shall provide properly qualified testing contractor who shall be responsible for supervising, coordinating, and performing all electrical field testing and checking work and who maintains a written record of all tests conducted.

f. Testing and checkouts shall be performed in the presence of the Engineer.

g. Contractor shall furnish four copies of all test results to the Engineer. Results sheets shall include date of test, personnel involved, items tested, type of tests and test data.

h. Any equipment or material damaged due to improper test procedure or test apparatus handling shall be replaced or restored to original condition by Contractor at his expense.

i. Safety devices including, but not limited to, rubber gloves and blankets, screens and barriers, danger signs, padlocks, etc., shall be used to protect and warn all personnel in the vicinity of the tests.

j. All test instruments used shall have a certified calibration sticker showing last date of calibration and expiration date.

2. Substation and Switchgear Equipment

All substation and switchgear equipment shall be subject to a field performance test. This test has to be performed by a qualified independent testing company and witnessed by MBTA personnel from the Power Systems and Equipment Area. This independent test company cannot be associated with the manufacturer of the supplied substation equipment. Field tests are to be performed to supplement the factory tests and to verify proper operation of equipment and proper calibration and coordination of protective devices. Contractor shall furnish and set up all specified equipment required for these tests. All work should be perform using the applicable guidelines of the National Electrical Testing Association (NETA) Acceptance Specification and Section 16950.

a. Load Break Switches:
   1) Cubicle heater operation.
   2) Calibrate and function test all relay devices.
   3) Check hardware, indicator lights, and insulators. (Torque if necessary).
   4) Kirk key evaluation.
   5) Blade and arc chute operation.
   6) Power factor lightning (surge) arresters.
   7) Dielectric tests. (Insulation and contact resistance)
   8) High potential tests. (Hi-pot).

b. Transformers:

   1) Double power factor excitation test with 10 kV tester.
   2) Hi-pot primary side.
   3) Megger secondary side.
   4) Transformer turns ratio (TTR) test.
   5) Core ground test.
   6) Insulation resistance test.
   7) Test cubicle heaters.
   8) Check all hardware, bushings and vibration mats.
   9) Visual and mechanical inspection.
   10) Test temperature control panel and verify alarm stages.
   11) Clean transformer.

c. 480 Volt Switchgear:

   1) Primary injection test of all breakers through all settings.
   2) Secondary injection test using the integral test panel trip unit through all the settings.
   3) Check and verify cell code types.
   4) Visual and mechanical inspection of all breakers.
   5) Insulation resistance test on all phases to all breakers.
   6) Dielectric tests on all 480 Volt buses.
   7) Test all relays and 47 devices with three phase power source.
   8) Test all meters. (kWh volt, ampere, and heater).
   9) Test all cubicle heaters.
   10) Evaluate Kirk key system.
   11) Test total operation of main breakers to tie breaker transfer schemes.

Before equipment can be energized, all tests have to be performed and verified with a copy of all test

results from the factory. Field performance tests and power system studies (such as short circuit coordination and evaluation study, protective device coordination and evaluation study, and ground grid test data) be submitted to the Power Systems and Equipment Area to be reviewed and verified before energization.

3. Substation Field Test Requirements

   a. Contractor shall formulate a complete Field Test procedure for equipment to be furnished and installed. Test procedure shall be comprehensive and shall include the required tests as specified in relevant standards of ANSI, NEMA, NETA and IEEE, supplementing the Factory Test procedure.

   b. The Contractor shall submit the test procedure to the Engineer for review and approval well in advance to the commencement of field tests. Engineer reserves the right to add, delete or make necessary changes in the test procedure. The Contractor shall arrange to conduct all the field tests as per the Engineer approved procedure. Since the Contractor is responsible for the performance and installation of the equipment furnished under this Section, he shall, therefore, prior to testing, verify that the installation is proper and in accordance with all applicable installation instructions specified herein.

   c. Perform continuity and dielectric tests to prove the correctness of circuitry.

   d. Relay and trip devices setting and coordination.

   e. Perform functional and operation tests of all equipment and of all devices and circuits.

4. Equipment and Instruments

   a. Check alignment and proper operation of all equipment including operating mechanisms, clearances, adjustment of contacts, and accessory equipment.

   b. Visually check each circuit breaker and operate manually. For each breaker with adjustable magnetic trips, set trips, Megger each pole for freedom from grounds, and check for proper current rating for connected circuit.

   c. Test indicating instruments, such as ammeters, voltmeters, and other instruments, by checking and adjusting pointers on zero scale with no load or voltage.

5. 600 Volt Wire and Cable

   a. Test in accordance with Section 16950.

6. Control and Devices

   a. All electrical controls shall be tested by trial operation of control equipment to verify that control circuits function as intended and are in agreement with manufacturer's instructions.

7. Substation Tests Reports

   a. The Contractor shall submit six certified copies of test reports for all the tests conducted at the factory and at field for Engineer's approval. Test reports shall be submitted to the Engineer within

seven days after completion of tests. In case of "Design Tests", test reports shall include original data, detailed calculation of test data used to arrive at the results and interpretation of results. Test reports shall contain the characteristic curves, etc. where required for interpretation of results.

3.07 SALVAGING AND SHIPPING OF EXISTING ELECTRICAL TRANSFORMER

A. The existing electrical transformer at the existing Unit Substation B2 shall be salvaged and shipped to Wellington Substation. This shall be coordinated with the MBTA Building Services Department.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. No separate measurement will be made for work required under this section but all costs shall be included in the pay item TUNNEL VENTILATION SYSTEMS which will be paid for on under a lump sum basis, complete in place including all terminations, relocation of existing feeders, testing, connections, staging, demolition and incidentals as shown on the Drawings and specified herein.

4.02 PAY ITEMS

ITEM NO.	DESCRIPTION	UNIT
1586.040	TUNNEL VENTILATION SYSTEMS	LS

END OF SECTION

SECTION 16312

DOUBLE ENDED UNIT SUBSTATION

PART 1 - GENERAL

1.01 GENERAL

A. This Section specifies furnishing, installing, connecting, testing, energizing and commissioning into regular service one (1) double ended unit substation at Maverick Station as shown on the Contract Plans.

B. The double ended unit substation specified in this Section is intended to supply 480/277 V load requirements of Maverick Station and also supply other auxiliary loads in the vicinity of the station.

C. The incoming 13.8 KV, 60 Hz primary AC power supply to the double ended unit substation will be provided from the Authority's 13.8 KV AC cable system. This Section specifies the requirements of equipment to be furnished for the above 13.8 KV power supply.

D. The dimensions of equipment indicated on the drawings are the maximum dimensions that are acceptable to the Authority.

E. In addition to factory testing of individual pieces of equipment as specified in Article 3.05 of this Section, each double ended unit substation shall be fully assembled at the factory including all interconnection wiring for inspection and witness testing by the Engineer/Authority. The equipment shall be disassembled for packing and shipping. Each wire/cable disconnected shall be properly tagged and protected for shipment.

F. The shipping sections shall be such as to permit transporting into and out of the intended location at Maverick Station without modifications to building or equipment.

1.02 SCOPE OF WORK

A. The Contractor shall furnish and install the secondary unit substation complete from the incoming line terminals to the outgoing line terminals as specified herein and as shown on the contract drawings.

B. The secondary unit substation shall consist of primary equipment, transformers, and secondary equipment as specified below. The manufacturer of the unit substation shall furnish and coordinate all major components of the substations, including incoming primary disconnect equipment section, transformers and low-voltage section with circuit breakers and metering components. Provide a single warranty covering all substation assemblies, transformers and components.

C. Connections between the primary devices and transformers shall be bus, and between the transformers and switchboard shall be flexible bus braid.

1.02 RELATED SECTIONS

A. Section 16120 - Wires and Cables
B. Section 16450 - Grounding

1.03 REFERENCES

A. The unit substation shall be designed, assembled, tested, and installed in accordance with latest applicable standards of NEMA, IEEE and ANSI, applicable to its three major sections.

1.04 SUBMITTALS

A. Shop drawings shall be submitted for Double Ended Unit Substation showing the designation in the title block of the drawing. Engineer reserves the right to make additions or deletions to any parts of the substations.

B. Drawings and Reference Data: The following drawings, diagrams, O&M- manuals, etc., shall be submitted for all equipment furnished, in accordance with the requirements in Section 01300 of Division 1 and Section 16050:

1. Master drawing index
2. Front view elevation
3. Floor plan
4. Top view
5. Single line
6. Schematic diagram
7. Nameplate schedule
8. Component list
9. Conduit entry/exit locations
10. Assembly ratings including:
    a. Short-circuit rating
    b. Voltage
    c. Continuous current
    d. Basic Impulse level for equipment over 600 volts
    e. kVA
11. Major component ratings including:
    a. Voltage
    b. Continuous current
    c. Interrupting ratings
12. Cable terminal sizes
13. Connection details between close-coupled assemblies
14. Composite floor plan of close-coupled assemblies
15. Impedance for transformers.

Where applicable, the following additional information shall be submitted to the Engineer:

1. Busway connection
2. Key interlock scheme drawing and sequence of operation.

1.03 STANDARDS

A. All major electrical equipment furnished under this Contract shall be in accordance with the latest applicable standards of NEMA, IEEE, ANSI, AAR, ICEA, OSHA, UL, National Electrical Code and Massachusetts Electrical Code with regard to Material, Design, Construction and Testing, except for variations as specified in this Specification. The standards applicable shall include but not be limited to the following:

ANSI C37.13	Low Voltage AC Power Circuit Breakers Used in Enclosures
ANSI C37.35	Guide for the Application, Installation, Operation, and Maintenance of High Voltage Air Disconnecting and Load Interrupter Switches.
ANSI C37.16	Preferred Ratings, Related Requirements, and Application Recommendations for Low Voltage Power Circuit Breakers and AC Power Circuit Protectors.
ANSI C37.17	Standard for Trip Devices for AC and General Purpose DC Low - Voltage Power Circuit Breakers
ANSI C37.20.1	Standard for Metal-Enclosed Low Voltage Power Circuit Breaker Switchgear
ANSI C37.40	Service Conditions and Definition for AC High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches and Accessories.
ANSI C37.51	Standard for Conformance Testing of Metal-Enclosed Low-Voltage AC Power Circuit Breaker Switchgear Assemblies
ANSI C37.90	Relays and Relays Systems Associated with Electric Power Apparatus
ANSI C39.1	Requirements for Electrical Analog Indicating Instruments
ANSI C57.12.01	General Requirements for Cast Coil Distribution and Power Transformers
ANSI C57.12.10	Requirements for Transformers 13.8 KV and Below
ANSI C57.12.91	Test Code for Cast Coil Distribution and Power Transformers
ANSI C57.13	Requirements for Instrument Transformers
ANSI C68.1	Dielectric Test Techniques (IEEE #4, ANSI/IEEE STD4 - 1978)
ANSI B1.1	Unified Inch Screw Threads
ANSI B1.10	Unified Miniature Screw Threads
ANSI Z55.1.61	Gray Finishes, Light Gray Color Chip No. 61
ICEA S-68-516	Ethylene-Propylene-Rubber Insulated Wire and Cable (NEMA WC-8) for the Transmission and Distribution of Electrical Energy
NEMA SG 3	Low Voltage Power Circuit Breakers
NEMA SG 5	Power Switchgear Assemblies
UL-44	Underwriters Laboratories, Inc., Flame Retardant Properties Test, for Rubber-like Insulated Wire
UL-508	Underwriters Laboratories, Inc., Industrial Control Equipment

B. Where any requirements specified herein or shown on Contract Plans exceed the above listed standards, the Contractor shall adhere to the higher standard. In case of conflict in requirements between two or more standards, decision of Engineer shall be final.

C. In case of Non-U.S. suppliers, equivalent British, European, Japanese or IEC standards are acceptable, provided a tabulation is furnished citing the comparison between the applicable U.S. and the equivalent Non-U.S. standards. In addition, the Non-U.S. suppliers shall note where U.S. standards are not met, for evaluation and approval by the Engineer.

D. All equipment and materials furnished under Division 16 shall conform to all Federal, State or Municipal laws for ordinances, and if any requirement shown or specified conflicts with such laws or ordinances, the Contractor shall make such changes as are necessary to meet said requirements. The cost of such changes shall be borne by the Contractor and shall be included in the Contractor's original bid. Where any standards shown on the Contract Drawings or specified herein exceed the minimum standards set by law, the Contractor shall adhere to the higher standard.

E. Where materials or equipment are specified to conform to the standards of the Underwriter's Laboratories, Inc., or to be constructed or tested, in accordance with the standards of the National Electrical Manufacturers Association or American National Standards Institute, the Contractor shall submit proof that the item furnished conforms to such requirements. The label of, or listing by the Underwriters Laboratories, Inc. will be acceptable as sufficient evidence that the item is in accordance with the Underwriter's Laboratories standard. A company listed as a member company of NEMA for an item under consideration will be acceptable as sufficient evidence that the item conforms to the requirements of the National Electrical Manufacturers Association. In lieu of such stamp or certification label listing, the Contractor may submit a written certificate from any nationally recognized testing agency adequately equipped and competent to perform such services, stating that the items have been tested and that the units conform to the requirements listed hereinbefore, including methods of testing of the specified agencies. Conformance with the agency requirement does not relieve the item from complying with any other requirements of the Specifications.

1.04 GENERAL REQUIREMENTS

A. The design of the equipment shall provide features for the safety of personnel during operation, maintenance, and repair.

B. All equipment and materials supplied by the Contractor shall be new, of recent manufacture and of highest grade as specified. They shall be resistant to moisture and corrosion to withstand their environment and operational conditions with minimum maintenance and long life.

C. Wherever practicable, all major electrical equipment and materials furnished under this Contract shall be the product of a single manufacturer. In the case of major items, the manufacturer shall maintain a service organization within a reasonable distance from the project which is properly staffed and equipped to make repairs as required.

D. Materials and equipment shall be essentially the products of a manufacturer regularly engaged in the manufacture of the product and the manufacturer shall have such products of comparable capacity and function to that specified in satisfactory use for a minimum of 10-years.

1.05 MANUFACTURER'S DRAWINGS

A. All units of measurement shall be in the United States English System. Unit of measurement of temperature shall be in degrees Celsius, denoted by degrees C. Drawings may use metric dimensions and tolerances, shown in parenthesis, provided the equivalent United States units are clearly shown on all drawings defining

General Arrangements and Interfaces, and on all drawings used for installation, repair, maintenance or disassembly. Drawings shall be prepared using terms and units standard to U.S. industry.

B. Unit of measurement for wire and cables shall be American Wire Gauge (AWG) up to size 4/0 and circular mils for larger sizes. Conductor stranding shall be as per ASTM.

C. All drawings shall be in English language only, irrespective of country of origin.

D. All drawings shall have a blank 3" x 4" space on the top right hand corner, clear of all markings, for approval stamping by the Engineer. If the Contractor's standard drawing does not provide this space, the drawing shall be prepared on the next larger sheet, or the 3" x 4" space may be provided elsewhere on the drawing.

1.06 BUS AND BUS CONNECTIONS AND JOINTS

A. The buses within equipment supplied by the Contractor shall be fabricated of high conductivity rectangular copper bars as specified herein. Buses shall be designed to carry rated currents without exceeding the maximum allowable temperature rise as specified in ANSI, NEMA and IEEE standards when operating at specified rated overloads. Bus connections and joints shall have an ampacity equal to that of the bus ampacity, and fabricated so that there will be no loss of conductivity during the life of the equipment.

B. The entire contact area of all bolted current carrying connections in copper buses shall be factory silver plated. Ring-plated method of silver plating and tin-plated contact surfaces will not be acceptable. Silicon bronze bolts, nuts and lockwashers, or approved equal, shall be used. Connections shall be made with a minimum of two 1/2" - 13 bolts at each end of the joint.

C. The Contractor shall coordinate all connections of equipment furnished under this Contract with existing equipment or with other equipment also furnished under this Contract.

D. Clearly visible permanent phase identification (A, B, C, Neutral or ground) of each bus inside the switchgear shall be provided. Also, nameplates specifying whether the buses are line side or load side shall be provided.

1.07 POWER AND GROUND CONNECTORS

A. All terminal lugs furnished for power and ground cables shall be heavy duty, bolted type, of high copper content alloy, complete with silicon bronze bolts, nuts and lockwashers. Lugs shall have tongues with either two or four 1/2" - 13 bolts, as specified, spaced per standard NEMA drillings, and four-bolt cable clamps. All contact surfaces shall be machined smooth and silver plated.

1.08 NAMEPLATES

A. Each major component of equipment shall have, as a minimum, the manufacturer's name, address, and catalog number, model, style or type on a nameplate securely attached to the item in an area easily accessible to normal visual demands by maintenance and service personnel. Nameplates for electrical apparatus shall conform to the referenced standards and as specified elsewhere in this Specification.

B. Each Switchgear assembly, HVLI switch unit circuit breaker and metering units, transformer, terminal box, and all panel mounted and individually mounted equipment and devices shall be provided with nameplates for proper identification. Door mounted devices shall also be identified in the rear with the designations indicated on manufacturer's connection diagrams. Internally mounted devices shall be similarly identified with nameplates and manufacturer's connection diagram designations.

C. Nameplates identifying major equipment shall have lettering two inches high, minimum. Two nameplates shall be provided, one on front, the second on the rear of the equipment.

D. Nameplates identifying circuit breakers and auxiliary units shall have lettering one inch high, minimum. Inscription shall include circuit breaker number and service. One nameplate shall be provided on front, the second on the rear of each unit.

E. Nameplates for panelboards, terminal boxes and similar equipments shall have lettering 3/4 inch high, minimum.

F. Nameplates for door mounted and internal panel mounted relays, meters, control and instrument switches, fuses and auxiliary devices and individually-mounted circuit breakers, disconnect switches, etc., shall have 1/4 inch, minimum, lettering. For protective and auxiliary relays, the nameplate inscription shall include device number and function. Nameplates for fuses shall note the type and rating of fuse, polarity and identify the circuit.

G. All nameplates shall be laminated plastic with dull white surface and black core unless otherwise specified. Letters shall be engraved through outer layer to expose black core. All exposed edges shall be beveled. Nameplates shall be fastened with machine screws. Use of self-tapping screws or adhesive will not be permitted.

H. The legends of all nameplates shall be submitted to the Engineer for approval.

1.09 WIRING AND TERMINAL BLOCKS

A. Wiring

1. All secondary and control wiring in equipment, including wiring on removable elements of circuit breakers, shall be ICEA type SIS or approved equal stranded tinned copper switchboard wire, rated for a minimum conductor temperature of 90 degrees C. Wire shall be insulated for 600 volts unless otherwise specified. Wire shall comply with UL-44 for flame retardant properties test of thermo-plastic insulated wire. Wire crossing hinged joints shall be similar except extra flexible, suitably protected against abrasion. Current and potential transformer secondary wiring and control circuit wiring shall be No. 12 AWG, or larger, unless otherwise specified.

2. Wiring shall be provided with ring type compression terminals with insulated sleeves at each termination. All wiring shall be identified at each termination by printing on wire jacket or on an insulating sleeve. Adhesive wire markers are not acceptable.

3. Wiring installed through openings in metal barriers or structural members shall be protected against abrasion by approved grommets.

4. Wire harnesses shall be supported with a bracket fastened to the enclosure via a tack-welded stud or a machine screw utilizing a "shake-proof" washer. Stud shall be welded and/or drilling and tapping for machine screws shall be accomplished before finish paint is applied. Nylon composite tie wraps shall be used for securing harness to the support. Wire support brackets attached to the enclosure with adhesives are not acceptable.

B. Terminal Blocks

1. Circuits requiring external connections shall be factory-wired to terminal block, readily accessible for field wiring entering from top. Sufficient number of terminals to satisfy all external connection requirements and 20 percent additional unassigned terminals shall be provided. Terminal blocks shall be heavy-duty, washer-head screw type with insulating barriers between circuits, rated 600

volts, unless otherwise specified, complete with marking strips and plastic covers. Similar terminal blocks, complete with properly tagged jumper wires, shall be provided at each shipping split to facilitate field assembly.

2. Current and potential transformer secondary leads shall be wired directly to terminal blocks before being wired to relaying, metering or control devices. Terminal blocks for current transformer leads shall be short-circuiting type. Transformer secondaries shall be grounded with No. 8 AWG wire running directly to ground bus without intervening splices or terminal box.

1.10 RELAYS, SWITCHES AND DEVICES

A. General

1. The type of relays, switches and devices used in the control and supervision of the supplied equipment shall have proven record of successful operation in similar application to the satisfaction of the Engineer.

B. Relays and Meters

1. All protective relays except solid state relays where approved by the Engineer and watt-hour meters shall be of draw-out construction, provided with semi-flush mounting cases. Relays shall be connected to external wiring through built-in test switches or connection blocks arranged to allow in-case testing of the relay. The protective relays shall be provided with manually re-settable targets (flags) for each function, rated for 120 Volts AC trip circuit.

2. All control and auxiliary relays shall be front connected, surface mounting type, with cover, suitable for use in switchgear equipment in accordance with ANSI C37.90. Operating coils of alternating current relays shall be suitable for continuous operation between 80 percent and 110 percent of rated voltage and for alternating current relays between 85 percent and 110 percent of rated voltage.

   a. The coils of interposing relays, Devices 201C and 201T, for interfacing with the existing supervisory system equipment shall be rated for operation on 120 Volt AC and shall have a burden of not more than 12.5 watts. Coils shall be provided with surge limiting diodes to suppress noise during operation which may cause momentary false indication. Contact shall be rated 30 ampere AC, minimum.

3. All indicating instruments shall be switchboard type, one percent accuracy, semi-flush mounted having metal scales with black figures on white background. They shall be approximately 4-1/2 inches square with a minimum of 240 degrees scale, furnished with anti-glare glass, unless otherwise specified.

4. Ammeters for space heater circuits shall be panel type, two percent accuracy, semi-flush mounting, approximately 2-1/2 inch square.

C. Switches

1. All control, selector and instrument switches shall be rotary type, provided with properly designated black escutcheon plates, clearly marked with white letters to show operating position, General Electric, Gould, Westinghouse or approved equal, unless otherwise specified.

   a. Breaker control switches shall be spring return to normal with escutcheon engrave TRIP-CLOSE, trip counter-clockwise, close clockwise, furnished with target and red pistol grip handle.

b. Breaker control mode selector switches, device 43 shall be three-position, maintained contact type with escutcheon engraved LOCAL-OFF-SUPV, off position at 12 o'clock, with black oval handle.

c. Instrument switches shall be maintained contact type, shall have an off position and black knurled round handle.

d. Selector switch for selecting the mode of operation of the 600 volt system, that is, normal mode or emergency mode as described in Article 2.01-C.2, shall be maintained contact type with escutcheon engraved AUTO-MANUAL, with black pistol grip handle.

D. Indicating Lamps

1. All indicating lamps shall be 55 or 24 volts, low burden, long life type, mounted in assemblies which include an appropriate series resistor, mountings and colored lenses. Lenses shall withstand continuous operation of the lamp without melting or other damage. Indicating lamps, shall be LED cluster lamps, in green, red or amber LED. No incandescent lamps.

2. Series resistors shall be rated to limit the voltage at lamp during operation to not higher than 85 percent of the design voltage of the lamp, with station battery float voltage applied to indicating lamp assembly terminals.

E. Fuses

1. All fuses for control, auxiliary, and metering circuits shall be located in such a position that they are easily and safely accessible. Fuses shall be of the nonrenewable, cartridge type.

a. Fuse holders and fuses installed in solidly grounded equipment assemblies shall be rated for 250 volts ac service. Fuses shall have a minimum interrupting rating of 20,000 amperes rms, symmetrical, at 250 volts ac and dc.

F. Test Switches

1. Test switches shall be provided for in-service testing and calibration of indicating instruments and other devices not furnished with built-in test devices and for removal of these devices from potential and current circuits without disturbing switchgear wiring. Each test switch shall be provided with a minimum of three poles for potential circuits and six poles for current circuits. Current switches shall be provided with features for short circuiting current transformer secondaries prior to disconnecting the instruments and devices from current circuits. The individual switch units shall be assembled on an insulated base provided with insulated barriers between each pole. Test switches shall be arranged for semi-flush mounting in front of the switchgear. Contractor shall furnish a set of necessary test plugs and jumper cables with each switchgear assembly.

1.11 SURGE ARRESTERS - Not Used

1.12 KEY INTERLOCK SYSTEMS

A. GENERAL

1. Tumbler settings of locks shall be different for each interlock system. Information related to lock settings and number of keys to be supplied will be furnished to the Contractor by the Engineer.

B. Key Interlock Scheme

1. Each primary interrupter switch at Unit Substation shall be provided with a key interlock system to prevent operation of the interrupter switch in either direction, unless the associated secondary main circuit breaker is open. To open the interrupter switch, following operations must be performed:

   a. Open the secondary main circuit breaker at the unit substation. The captive key at the circuit breaker is now free to be turned and removed. Turning of the key will lock the circuit breaker in open position.

   b. Insert the key in the lock at the interrupter switch and turn to unlock the switch operating mechanism. Key is now held captive.

   c. The interrupter switch can now be opened.

   d. Reserve sequence to restore service.

2. In addition, each interrupter switch shall be provided with a mechanical interlock to prevent opening of the front door when the interrupter switch is in the closed position. A Kirk key interlock in lieu of the mechanical interlock will be acceptable.

1.13 POTHEADS AND TERMINATION

A. Potheads shall be indoor, three-conductor, soldered-joint type, suitable for terminating three-conductor, 15 KV, shielded, paper insulated lead covered cable. Potheads shall have cast bodies of non-ferrous material complete with uncut wiping sleeve. Insulators shall be of high strength wet-process porcelain, rated 15 KV, designed to withstand an impulse test of 110 KV.

B. Potheads shall be mounted on split adapter plate to facilitate removal. Bodies of potheads at 15 KV switchgear for incoming feeders shall be insulated from switchgear structure.

1.14 SUPERVISORY CONTROL

A. The equipment furnished under these specifications shall include control and indication circuits wired to terminal blocks for the supervisory control and indication functions specified herein. All auxiliary contacts provided for indication circuits shall have a minimum rating of five amps at 125 volts dc continuous and 10 Amps at 125 Volts, AC continuous as needed for each application.

1.15 FINISH

A. All metal work shall be carefully finished to remove sharp edges and burrs.

B. Thoroughly clean all surfaces to be painted and treat with a rust inhibiting phosphatized coating prior to the application of two finish coats of semi-gloss ANSI 61 light gray paint, unless otherwise specified.

C. Submit manufacturers standard finish details for engineers review and approval.

1.16 WORKMANSHIP

A. Prepare all surfaces of equipment so that they are smooth and free of gaps, burrs, sharp edges, wrinkles, waves, blemishes, or other unsightly defects which would detract from a neat appearing finished product. Enclosing structures shall have sufficient structural reinforcements to insure the surfaces shall remain plane and plumb, to restrain vibration, and to provide necessary strength and rigidly during shipment, installation, and operation.

1.17 SPECIAL TOOLS AND HANDLING PROVISIONS

A. Furnish and deliver with the equipment all special tools and equipment handling devices as recommended by the component manufacturers, for the adjustment and maintenance of all equipment furnished under these specifications. Special tools are defined as tools not readily available on the open market.

1.18 DELIVERY AND STORAGE

A. Equipment and materials shall be delivered to the site in original containers, suitably sheltered from the elements, but readily accessible for inspection by the Engineer until installed. All items prone to moisture damage, such as controls and electrical apparatus, shall be stored in dry, heated spaces. Equipment and materials shall be tightly covered and protected against dirt, water, chemical and mechanical injury and theft. Damage or defects which occur before acceptance of the work shall be repaired or replaced as directed, without additional cost to the Authority.

B. Ship each unit substation in assembled sections of maximum size taking into consideration available access for each switchgear as shown on the Contract Drawings.

C. Temporary Bracing. Brace and package each section to permit hoisting, lowering, and skidding into position. Clearly label all temporary internal bracing of each section as TEMPORARY BRACING: TO BE REMOVED BEFORE OPERATION.

D. Protection Against Concealed Damage. Package equipment, which may be subject to non-visible damage during shipment with mechanical impact recorders which will register the maximum acceleration to which the equipment has been subjected along each axis. Unpack such equipment in the presence of the Engineer.

1.19 LIFTING DEVICE AND MOBILE TRANSFER TRUCK

A. A mobile circuit breaker lifting device of the Hydraulic Piston type and a portable transfer truck to raise, lower and transfer the circuit breakers shall be provided for each double ended unit substation.

B. The device shall be capable of removing and inserting breakers from any position in a vertical stack with complete case and safety.

C. The lifting mechanism shall not be mounted either temporarily or permanently on the unit substation structure. Provide a permanently - mounted crane on top of the switchgear to lift breakers in and out of the cubicles.

1.20 CIRCUIT BREAKER TEST CABINET

A. Contractor shall provide a wall mounted test cabinet for electrical operation of circuit breakers at location remote from the switchgear. The test cabinet shall include a control switch, or a set of pushbuttons, to close and trip the breaker, position indicating lights, ten feet of control cable with a connector at the end for connection to the breaker, a set of properly sized fuses to protect the control circuit and screw type terminals for No. 8 AWG conductors of 125 volt dc or 120 Volt AC control supply. The wall mounted test cabinet shall match the type of breakers being utilized.

B. Provide two test kits, for use with solid - state trip device for checking and calibration, operating from standard 20 ampere, single phase 120 volt outlet. Test kits shall include jack and receptacle to connect to solid state trip device, ammeter, second counter and test switches to enable testing of all tripping functions.

C. Provide a work table for bench testing and maintaining the draw out circuit breakers using the circuit breaker tester and other equipment as described in item above.

D. Provide a minimum of two (2) grey lockable galvanized steel storage cabinets for storage of accessories and spare parts containing the following:

1. fuse pullers

2. spare fuses (high and low voltage)

3. high voltage gloves, coat and hood

4. set of tools required for breaker maintenance, wrenches, screwdrivers and sockets.

5. breaker test kit

6. catalogs/documentation for all switchgear

7. self powered high voltage status scope

PART 2 - PRODUCTS

2.01 GENERAL REQUIREMENTS

A. Equipment Environment

1. Double Ended Unit Substation specified in this Section shall be designed for operation in an environment with 40 degrees C ambient temperature.

2. The equipment shall be designed to resist dynamic earthquake loadings based on the Massachusetts State Building Code.

B. Service Conditions

1. The 13.8 KV, 60 Hz ac power to the incoming load interrupter switch units will be supplied from Loop feeders from the Authority's 13.8 KV ac cable network. It is expected that the maximum short circuit capacity of the 13.8 KV ac source, from the MBTA network, at the incoming feeder terminals of load interrupter switch will not exceed 500 mVA with an X/R ratio of 8.

C. Proposed Control and Supervision

1. General

a. The switchgear equipment furnished by the Contractor shall be provided with protective, control and interlocking features to safeguard the various equipment and to permit both local and/or supervisory control as specified herein and as shown on the attached sketches. The Specification and sketches indicate the basic protection and control requirements which shall be adhered to.

b. The following device numbers are used for specifying the control and supervision scheme. These device numbers shall also be used by the Contractor in the schematics and wiring diagrams, arrangement drawings and bill of materials:

DEVICE NO.	FUNCTION
1	AC circuit breaker local control switch
30	Annunciator

43	AC breaker control mode selector switch
47	Phase sequence
47X	Auxiliary relay
48T, TH	Transformer winding overtemperature device alarm - TRIP
52	AC circuit breaker
74	Alarm relay
86	Lockout relay
89	Load interrupter switch, fused or unfused
201C	Supervisory interposing relay - close
201T	Supervisory interposing relay - trip
27	Undervoltage Relay
51G	ORO Sequence Ground Fault System

D. Automatic Transfer Operation of Bus Tie

Provide for automatic transfer Device No. 83 of the main and bus tie circuit breaker as follows:

1. Normal Operation

   a. Both main circuit breakers closed

   b. Bus tie circuit breaker open.

2. Loss of voltage of either 480 volt bus: An undervoltage relay Device No. 27 shall operate, initiating local annunciation and simultaneously energizing a time delay relay Device No. 2. After an adjustable (0-10 sec) time delay of 5 (five) seconds, and if voltage is present at opposite end, tripping of main circuit breaker and automatic closing of the tie circuit breaker shall result.

3. Interlocks

   a. Prevent closing of tie circuit breaker into a faulted bus either phase to phase, line to neutral and/or line to ground or unless one main circuit breaker is open.

   b. Trip the tie circuit breaker whenever both main circuit breakers are closed.

   c. A 43 (auto-manual) latching type device shall be installed at tie breaker location to select automatic or manual transfer. This switch position will be monitored by SCADA, with amber indicating lamps.

   d. A three position 43 (supervisory) device shall be installed at tie breaker location to select "supervisory" "off" and "local" control. This switch position will be monitored by SCADA and be independent of the supervisory 43 device.

4. Phase Indication

   a. A phase sequence voltage relay, Device No. 47, shall indicate correct phase sequence between the 480 volt secondaries of Line 1 and Line 2.

5. Mode of operation of 480 V System

   a. The unit substation control, protection and interlocking circuits shall be arranged for the following mode of operation of 480 volt system:

- Under normal mode of operation the secondary circuit breakers of transformer No.1 and No.2 are closed, feeding their respective buses. The bus tie circuit breaker will be open. Electrical interlock will prevent closing of the bus tie circuit breaker when both secondary circuit breakers are closed.

- Under emergency mode of operation, the secondary circuit breaker of either transformer No.1 or transformer No. 2 and the bus tie circuit breaker are closed. Bus No. 1 and 2 are thus fed from a single transformer.

b. The change-over from normal mode of operation to emergency mode may be selected by Auto-Manual two position selector switch provided in the switchgear. When the switch is in Auto position the control circuitry of the transformer secondary breakers and the bus tie breaker shall be arranged for the following sequences of operation: Each main and tie breaker shall have an individual 43 supervisory switch.

- Under normal operating condition the loss of voltage on secondary of either transformer shall cause the phase sequence and undervoltage relay (Device 47) in that transformer secondary side to drop out and trip its secondary breaker through an auxiliary relay (Device 47X) providing normal voltage is available on the other bus.

- After tripping of one of the secondary circuit breakers, due to loss of voltage as specified above, the bus tie circuit breaker shall be closed automatically. Thus the system is now on emergency mode of operation. The automatic closing of bus tie circuit breaker shall be prevented if the secondary circuit breaker is tripped by its overcurrent devices.

c. Return to normal mode of operation, after return of voltage to normal on the secondary of transformer which secondary breaker had tripped, shall be by performing the following operating sequence:

- Open the bus tie circuit breaker by its control switch (Device 1) at the switchgear.

- Reset auxiliary relay (Device 47X).

- Close the open secondary circuit breaker by its control switch (Device 1) at the switchgear.

d. Normally open contact of the bus tie circuit breaker shall be wired to the supervisory terminal box for providing supervisory indication of emergency mode of operation.

6. Basic Breaker Control and Interlocking

a. The control circuits of secondary and tie circuit breakers in the 480 volt switchgear shall be arranged for both local control and remote control via Authority's supervisory system.

b. Three (3) three-position (LOCAL-OFF-SUPERVISORY) each control mode selector switch (Device 43) for transferring all the three (2 secondary main and one bus tie) circuit breakers from local control to supervisory or supervisory to local control, shall be provided. In addition to the contact required for the control circuit transfer, the switch shall be provided with a contact (closed in the "SUPERVISORY," open in the "LOCAL" position of the switch) for remote switch position indication via Authority's supervisory system. Each of these three brakes shall also be provided with control switch (Device 1).

c. All control switches (Device 1) located at the switchgear shall be provided with green, white and red indicating lights, mounted above the switch (green at left, red at right). The red light shall be connected in series with "a" contact of the breaker and breaker trip coil to indicate breaker closed position and also to monitor the breaker trip circuit. The white, indicating light shall indicate the mechanism charged condition. The control switches shall be provided with slip contacts so arranged that the manual trip of the breaker will not actuate the circuit breaker auto-trip alarm. Similarly, the auto-trip alarm shall not be actuated if the circuit breaker is tripped via the supervisory system.

d. The control switch (Device 1) and indicating lights of 480 volt secondary circuit breakers and bus tie circuit breaker shall be provided in front of the breaker it controls to close and trip the breaker when the removable unit is in the "operating" or "test" position. Control mode selector switch (Device 43) which is common to all the three circuit breakers shall be provided in front of the bus tie circuit breaker for selecting the mode of operation of circuit breakers in the "operating" position. Any circuit in the "test" could be operated only from its control switch (Device 1) in front of the circuit breaker.

e. Control circuits shall be arranged to provide the following scheme of operation:

- With the control mode selector switch (Device 43) in the "Supervisory" position, local closing functions will be disabled and the circuit breaker can be closed only via the Authority's supervisory system and only when the breaker removable element is in the "operating" position.

- The circuit breaker can be tripped either via the supervisory system when the circuit breaker removable element is in the "operating" position only or by the control switch at the switchgear in both "operating" and "test" positions of breaker removable element.

- With the control mode selector switch (Device 43) in the "Local" position, all supervisory functions will be disabled.

- Each of the three circuit breakers, two secondary circuit breakers and one bus tie circuit breaker, can be closed or tripped from the control switch at the switchgear in both the "operating" and "test" positions.

- With the control mode selector switch (Device 43) in the "OFF" position, all local and supervisory control functions will be disabled, except the tripping function of the control switch at the switchgear.

f. Control mode selector switch (Device 43) shall be mounted directly above the breaker control switch (Device 1) of the bus tie circuit breaker.

g. The protective device and relay circuitry of the breakers shall not be affected by the control mode selector switch (Device 43); when actuated these devices shall trip the respective breakers regardless of the position of the selector switch (Device 43).

h. The 480 volt ac switchgear is normally operated with the bus tie circuit breaker between the two sections open. Electrical interlock shall be provided to achieve the following mode of operation.

- Allow closing of any two of the three circuit breakers at any one time.

- Prevent closing of the other secondary circuit breaker when one of the secondary circuit breaker and tie circuit breaker are closed.

i. Automatic tripping and lockout of secondary circuit breaker for actuation of transformer protective devices are described in Article 2.01.

j. Automatic bus transfer scheme for low voltage switchgear in the event of loss of voltage on the secondary of any one of the transformers is described in Article 2.01.

4. Supervisory Control and Indication

a. The Authority will not be providing a computerized supervisory system for remote control of circuit breakers in various stations throughout MBTA network and monitoring of equipment and auxiliary circuits in substations. The master station and the computer equipment of the supervisory system will be located at the Authority's Operations Center. A remote terminal equipment cabinet will be provided at each of the passenger stations in which the unit substations specified under this Section will be located.

b. The Contractor shall furnish, install and connect all interposing relays (Device 201C, 201T) for proper interfacing of the breaker control circuits with the Authority's supervisory equipment, and provide a normally open contact from each supervisory-controlled circuit breaker for remote breaker contact position indication. Contractor shall also provide all contacts, relays and devices necessary for remote monitoring of below listed equipment and circuits. The interposing relays shall be supplied from the 120 Volts AC control bus of the switchgear through a set of fuses. The load side of positive fuse, one side of the interposing relay coil and all supervised contact devices shall be wired to outgoing wiring terminal blocks at switchgear. These circuits shall be extended to a terminal box near the supervisory equipment cabinet. Contact Power could be 125 Volts DC or 120 Volts AC, to be determined by manufacturer.

c. The wiring between the unit substation and supervisory terminal box and also between the supervisory terminal box and SCADA RTU shall be furnished and installed by the Contractor.

d. The furnishing and installation of supervisory interface terminal box and SCADA remote terminal unit (RTU) is not included under this Section.

The following circuit breakers at the substation shall be provided with devices for remote close trip control and indicated via Authority's supervisory system:

- Secondary circuit breakers - Latching relay automatic position
- Bus-tie circuit breakers - Latching relay manual position

e. The following circuits and devices included under this Section shall be provided with monitoring contacts for remote indication via Authority's supervisory system.

- Position of control mode selector switch of supervisory controlled breakers (Device 43) and AUTO-MANUAL Selector Switch for 480 volts automatic transfer scheme.
- Lockout relay (Device 86), of secondary breakers.

- Substation transformer winding hot spot temperature indicator (Device 49A+49T), one for each transformer.
- Emergency mode of operation.
- Load break switch - Line 1
- Load break switch - Line 2
- Loss of control power
- All feeder breakers
- Loss of 13.8 KV power - Line 1
- Loss of 13.8 KV power - Line 2

f. If the transformer protective device specified above cannot be provided with required number of independent contacts for local annunciation, supervisory indication and trip functions, Contractor may provide multiplying relay (s) as required. The contacts of the protective devices shall be first wired to multiplying relays, and independent contacts of multiplying relays shall be utilized for the various functions specified.

E. Protective Device Coordination

1. The Contractor shall furnish protective devices in the switchgear equipment as listed elsewhere in this section, or as may be required, to provide reliable coordinated protection for the system. All such devices shall be adjustable and shall be factory calibrated to provide the general scheme of protection outlined below. The Contractor shall submit to the Engineer, for approval, the recommended settings of the protective devices, also show the settings on log-log paper for graphic proof of the required device coordination.

2. Transformer secondary circuit breaker shall provide:

   a. Protection of transformer windings from low voltage switchgear faults.

   b. Protection of low voltage switchgear and transformer from overheating due to overload.

   c. Backup protection for distribution circuit breakers.

3. The following transformer protective device shall cause the automatic tripping of the secondary circuit breaker through the lockout relay (Device 86). The lockout relay shall cause the lockout of circuit breaker in open position until the lockout relay is manually reset. The lockout relay, through its "b" contact, shall create loss of voltage condition to phase sequence and undervoltage relay (Device 27) thus setting automatic transfer scheme into operation:

   a. Transformer winding hot spot overtemperature second step (Device 49TH).

4. The following conditions shall cause the automatic tripping of the secondary circuit breaker:

   a. Fault on distribution feeders - phase and ground not cleared by distribution circuit breakers.

   b. Overcurrent condition on 480 V switchgear bus.

5. Contractor shall furnish phase and ground selective coordination curves for the system starting from 13.8 KV primary circuit fuse of the transformer through low voltage secondary circuit breaker, bus tie circuit breaker and distribution circuit breakers. Protective device coordination curves shall be submitted on K & E Co. log paper, showing relay, trip device coordination of all equipment. Details of protection provided in the 13.8 KV switchgear at substations or data on utility feeders required for preparation of coordination curves will be furnished to the Contractor.

6. Contractor shall provide ground fault protection scheme meeting the requirements of National Electrical Code for service entrance equipment with a transfer scheme. The preferred protection scheme is by neutral relaying. Contractor shall submit the proposed scheme for Engineer's approval along with the shop drawings of equipment.

2.02 DOUBLE ENDED UNIT SUBSTATION

A. General

1. Double ended unit substation specified under this Section shall conform to the requirements of this Section and also to the requirements of applicable ANSI and NEMA Standards and to the NEC Code as applicable.

2. The equipment shall be designed, manufactured, tested, installed and commissioned for 13.8 KV, 60 Hz incoming feeders on the primary side of the transformers and outgoing feeders on the secondary side of transformers supplying load at 480/277 V, 3 phase, 60 Hz as shown and specified.

3. The double ended unit substation shall consist of two of each of the following sections:

   a. 13.8 KV ac incoming line and transformer primary feeder section.

   b. Epoxy Cast Coil transformer section. (Primary and secondary are totally encapsulated with epoxy, no hybrids will be acceptable.)

   c. 480/277 volt low voltage section.

   All the above sections of each double ended unit substation shall be designed and assembled together, to form a mechanically and electrically coordinated, free standing dead front assembly. The sections of the assembly shall be mounted on a common base channel and rigidly bolted to each other. Each section of the assembly shall be suitable for lifting as a single unit in one piece (without base channel) without the section being distorted or otherwise damaged. Each section shall consist of rigid self-supporting and self-contained electrically welded or rigidly bolted steel structures enclosed with not less than 12 gage formed steel sheets. All sections shall be of the same depth and height arranged for front and rear lineup, mounted on concrete housekeeping pad.

4. Full height hinged doors shall be provided in front of the interrupter switch and the transformer sections. Doors shall be formed of sheet steel and shall be properly reinforced against distortions by suitable flanges and stiffening members. Hinges shall be heavy duty, of a type approved by the Engineer. All doors shall be securely fastened in the closed position with a minimum of two latches easily opened without the use of tools. Doors shall be provided with stops to hold them securely in the open position.

5. Bolted-on sheet steel covers hinged on one side shall be provided in the rear for access to the 13.8 KV incoming section units and to the transformer. Hinged covers shall be provided in the rear of low voltage section units.

6. A continuous copper ground bus 2 inch x 1/4 inch, or larger, shall be provided through the entire length of the unit substation. The enclosure of each section shall be grounded to this bus. A bolted type terminal lug with two bolt tongue, shall be provided, in accordance with Article 1.07, this Section at each end of ground bus for field connection to the station ground. The connectors shall be suitable for stranded copper ground cable within the range of No. 4/0 AWG through 500 kc mil.

7. The sound level of the unit shall not exceed the limits specified in ANSI C89.2 and NEMA ST-20.

8. Control wiring and terminal blocks shall be provided in accordance with Article 1.09, this Section.

9. Instrument transformer secondaries shall be grounded with No. 8 AWG wire running directly to ground bus without intervening splices or terminal blocks.

10. Relays, switches, indicating lights and instruments shall be provided in accordance with Article 1.10, this Section.

11. All surfaces of the structure shall be furnished in accordance with Article 1.15, this Section.

12. One gallon of matching touch-up paint shall be shipped with the unit substation.

13. Key interlock system shall be provided in accordance with Article 1.12, this Section.

14. Potheads for 15 KV cable shall be provided in accordance with Article 1.13, this Section.

15. Contacts for supervisory indication and control shall be provided in accordance with Article 1.14, this Section.

16. The Contractor shall be responsible for the proper application and satisfactory operation of each section and component furnished under this Section of the Specification. Proposed designs and materials which in the judgment of the Engineer would require unreasonable and/or frequent maintenance, repair or replacement will not be accepted.

17. Phase sequence of buses, leads and terminals in the equipment shall be A, B, C top to bottom, left to right and front to rear. Phases shall be identified per NEMA Standards and as specified for buses in Article 1.06 - B of this Section.

18. In addition to nameplates specified in Article 1.08 of this Section, Contractor shall provide a nameplate on the front and rear of the Incoming Line Section and Transformer Section, engraved "Danger, 13,800 VOLTS". The nameplate shall have white letters, 2 inches high, minimum, on red background. The legends of nameplates shall be submitted to the Engineer for approval.

19. Contractor shall provide means of grounding incoming 15 KV line side and main buses for maintenance purposes without actually entering inside the cubicles and installing clamps on the buses. Details of provision proposed by the manufacturer shall be submitted for Engineer approval. Typically using a total of 8 ground balls per switch, one per phase line and load and two on the ground bus, facing the front of the switch.

20. Provide nameplates on all devices, meters, switchgear, and cubicles. The back side of each individual cubicle must be labeled. All nomenclature shall be approved by the MBTA's Power Systems and Equipment Area.

21. Provide SCADA indications (open and close) for all breakers in the switchgear.

22. Provide SCADA control (close and trip) for the main and tie circuit breakers.

23. Provide SCADA indication for loss of control power and loss of 13.8 KV voltage on either side of the switchgear.

24. Provide 43 switch devices for the main secondary circuit breakers and the tie breaker. These switches are three position switches that selects "supervisory" "off" and "local" control. These switch positions will be monitored by SCADA.

NOTE: In items 22 through 25 it is always the intention that the SCADA wiring from the point of origin of each SCADA point to a terminal block in the switchgear. From here it is then wired from this terminal block to another terminal block within the SCADA interface panel. This panel should be dedicated exclusively for the Power Systems and Equipment SCADA system, separate from any other system on the property. Wiring for the SCADA system use form C relays and form C wiring (three wire method). The minimum size wire will be #12's, use SIS wire inside the switchgear and THHN/THWN in a minimum of 1" RGS, conduit from the switchboard to SCADA interface panel.

B. 13.8 KV Incoming Line, Medium Voltage Switches and Transformer Primary Feeder Section.

1. When the incoming 13.8 KV feeders are from the Authority's cable system, this Section shall have two non-fused air interrupter switch units for incoming cables, one fused air interrupter switch unit for transformer primary feeder, one metering unit and one transition unit, if required.

2. Fused interrupter switch unit shall be furnished with a set of three indoor type power fuses of the self contained interruption type mounted on non-disconnecting supports suitable for operation on 13,800 volt, 60 hertz system. Fuses shall be of the general purpose current limiting type as defined in ANSI C37.46-1969, having an interrupting rating of 63,000 amperes rms asymmetrical, 108,000 amperes symmetrical at rated voltage.

3. Each fused interrupter switch unit shall consist of fused interrupter switch, as specified elsewhere in this Section, with pothead (s) for incoming cables entering from the top or bottom and terminal lugs for the 15 KV, shielded cables to the transformer primary terminals.

4. Fused interrupter switch shall be of the nominal 13.8 KV class, three pole, single throw, air break, stationary type, designed for operation on 60 hertz, having the following ratings:

• Nominal three-phase rating of associated switchgear	500 mVA
• Rated maximum voltage	15.0 KV
• Rated withstand test voltage:	
iow frequency (rms)	36 KV
Impulse, crest	95 KV
• Rated continuous current, minimum	20 A
• Contact interrupting rating, minimum	600 A
• Rated momentary current, asymmetrical (rms)	40 KA
• Three second current carrying capability (rms)	25 KA
• Fault closing capability asymmetrical (rms)	40 KA

5. Fused interrupter switch shall be of unitized three pole design, mounted on rigid all welded steel frame to assure positive three phase operation. Each pole shall be equipped with a main blade and a spring loaded auxiliary blade operating in an arc chute. All contact surfaces shall be silver plated.

6. Fused interrupter switch shall have manually operated, quick-make, quick-break spring stored energy type operating mechanism. An operating handle shall be provided for manually charging the spring and manually closing and opening the switch. A spring-defeat mechanism shall be provided to permit slow closing and opening the switch for maintenance and adjustment. Mechanical indicators

shall be provided to indicate the charged condition of the operating mechanism. The indicator shall have only metal-to-metal linkage. No chains or cable shall be used.

7. Provide high strength, non-hygroscopic, track resistant porcelain for bus and switch insulators, switch drive rod, barriers between phases and barriers between outer phases and the housing.

8. Provide auxiliary switches for indication and alarm circuits, each interrupter switch unit shall be furnished with a minimum of four "a" and four "b" spare auxiliary switch contacts easily convertible in field. These spare contacts shall be wired to outgoing wiring terminal block for Authority's use.

9. The transformer primary feeder fused interrupter switch shall be provided with the following interlocks:

   a. Key interlock with 15 KV auxiliary feeder breaker in 15 KV switchgear in accordance with Article 1.12 this Section to prevent the operation of the interrupter switch when the feeder breaker is closed.

   b. Mechanical interlock to prevent opening of the incoming line section door when the interrupter switch is in the closed position.

10. Each of the primary power supply feeder cables shall be installed with two removable neon glow tubes per phase for "feeder alive" indication. The glow tubes shall be mounted for observation through front and rear windows of non-shatter material located at a convenient viewing height. The glow tubes and mounting bracket assemblies shall be insulated from the bus and removal of the glow tubes and/or mounting bracket shall not infringe upon the integrity of the bus insulation. The glow tubes shall be arranged to obtain adequate brilliancy for observation in a well lighted area. The neon glow tube shall not reduce the impulse withstand level of equipment.

11. A flexible copper braided ground connection shall be provided from the switch operating lever to the ground bus in the unit.

12. Potheads if applicable shall be in accordance with Article 1.13, suitable for terminating three conductor, No. 4/0 AWG, 15 KV, Class H shielded copper cable manufactured per MBTA Standard Specification P-73C.

13. Load side of the switch shall be either bus connected or cable connected to the transformer primary terminals. In either case, adequate bus or cable supports shall be provided.

14. Interrupter switch compartment shall be equipped with a visual means of viewing the position of switch blades without opening section door.

15. Incoming line section shall be provided with one or two hinged doors in front depending on the manufacturers preference.

16. Instrument Transformers

   a. Instrument transformers shall be of the dry type. Transformers and associated wiring shall have mechanical strength and thermal rating commensurate with the rating of the associated equipment.

   b. Voltage transformers for indication and metering shall have ratios as required for a minimum thermal rating of 1,000 volt amperes with 55 degrees C rise above a room ambient of 40 degrees C, and an accuracy of 0.3 with ANSI standard W, X and Y burdens, 0.6 with Z burdens, and 1.2 with ZZ burdens. Voltage transformers shall be equipped with current

limiting primary fuses and shall be mounted on draw-out or tilt-out carriages. The front of the carriages shall be designed to close the section when the transformers are in the operating position. Primary contacts for the draw-out feature shall be designed to close the section when the transformers are in the operating position. Primary contacts for the draw-out feature shall be of a design which will ensure continuous positive contact pressure. Carriages shall be of sufficiently rigid design to maintain proper alignment of the primary contact. Visible grounding devices shall be provided to ensure that the draw-out carriage mounted voltage transformer primary terminals are grounded when the carriage is withdrawn. A flexible braided strap shall be provided for bonding the draw-out carriage to the equipment enclosure.

c. All voltage transformer primary circuit connections from the primary fuses shall be of No. 2/0 AWG, minimum, copper wire, fully insulated for 15 KV. Connections from the fuses to the high voltage terminals of the transformers shall be No. 6 AWG minimum, copper wire, fully insulated for 15 KV. Phase-to-phase and phase-to-enclosure distances shall be based on in-air clearances, assuming bare conductors.

d. Un-grounded conductors of voltage transformer secondary circuits shall be fused. Fuses shall be of the dual element, cartridge type, rated 20 amperes, 250 volts, mounted in barrier-type, porcelain base fuse holders.

e. Current transformers for indication and metering shall be of the window-type, with the ratio and accuracy class requiring a rated 600 volts, minimum, and designed to withstand full wave impulse test of 10 KV. The primary circuit bus bar shall be located at the center of the current transformer window, firmly supported, and fully insulated for 15 KV. The installation of current transformers shall withstand the dielectric and impulse tests specified for high voltage section.

f. Frames and cases of the current and voltage transformer, the secondaries of the current transformers, and the common secondary conductor of the voltage transformers shall be grounded to the equipment ground bus. Grounding of the voltage transformer and the carriage to the ground bus shall be made with an extra flexible grounding cable. All grounding conductors shall be made as short as possible, not grouped with other conductors, and shall be No. 6 AWG wire or larger. Ground wires shall be continuous without splices or intermediate connections. The current transformer ground wire shall be separate from the voltage transformer ground wire. The case ground wires shall be separate from the ground connections to the instrument transformer secondary wiring.

17. Detail of Equipment

a. 13.8 KV Incoming Line, Medium Voltage Switches and Transformer Primary Feeder Section supplied from the Authority's 13.8 KV ac system.

Each Section shall consist of the following:

- One - Fused 600 ampere load break switch unit, interlock and potheads with key interlock with the secondary main circuit breaker, cable or bus connection to primary of transformer for 3/c #4/0 AWG P1LC cable.

- One - Metering compartment with 14400 - 120 V draw-out PT's with primary and secondary current limiting fuses, 0-18 KV transformer rated voltmeter switch to read line to line to ground/neutral and monitoring contacts.

- One - Bus transition unit (optional)

- Nameplates for all units.

- Cubicle space heaters in all units with one common ON-OFF switch, ammeter, and blue indicating light rated 120 volt/250 watts.

b. Dipped fiberglass reinforced epoxy bus insulation, bussing rated for 15 KV on all 3 (three) phases of the switch bussing. Spacing criteria for the bus bars shall also be spaced as if they were not insulated.

c. Phase conductor 1" diameter ground ball stud and cover shall be installed on each phase conductor on the line and the load side of the switch. This will simplify grounding of the switch with two 3-way grounding jumpers to a ground bus with its associated ground balls and stud covers located at the bottom front of the cubicle. (A total of 8 ground ball studs and covers per Load Break Switch).

d. Limit switch installed on switch arm mechanism for SCADA supervisory system, complete with all the associated wiring back to SCADA interface terminal panel.

e. Load break disconnect switches are to be manual and motorized with SCADA capabilities, 120 volt AC relays. Potential fuses, if applicable, shall be mounted on a draw type table disconnect (i.e. open door draw out/disconnect pot fuses).

f. Plastic phase partitions with nylon nuts and bolts, associated mounting hardware, clips and brackets. Tie wraps will not be accepted.

g. The new load break switches must be equipped with a double Kirk key type interlock to prevent opening of the load break switch without first opening the associated secondary main circuit breaker. Once the secondary main breaker and the load break switch are open, the second Kirk key is needed to open the load break switch compartment.

h. Medium Voltage Load Interrupter Switch

1. The metal-enclosed load interrupter switches shall consist of dead front, completely metal-enclosed vertical sections containing load interrupter switches and fuses (where shown) of the number, rating and type noted on the drawings or specified herein.

2. The following features shall be supplied on every vertical section containing a three-pole, two-position open-closed switch:

   - A high-impact viewing window that permits full view of the position of all three switch blades through the closed door.

   - The door shall be interlocked with the switch so that:

     - ❖ The switch must be opened before the door can be opened.
     - ❖ The door must be closed before the switch can be closed.

   - A grounded metal barrier in front of every switch to prevent inadvertent contact with any live part, yet allow for a full-view inspection on the switch blade position.

- Provision for padlocking the switch in the open or closed position and permanent OPEN-CLOSED switch position indicators.

3. Vertical section construction shall be of the universal frame type using die formed and bolted parts. All enclosing covers and doors shall be fabricated from steel whose thickness shall be equal to or greater than those specified in ANSI/IEEE C37.20.3. To facilitate installation and maintenance of cables and bus in each vertical section, a removable top cover and a rear hinged padlocked door with three-point latch shall be provided.

4. Each vertical section containing a switch shall have a single, full length, flanged front door and shall be equipped with two rotary latch-type padlocked handles. Provision shall be made for operating the switch and storing the removable handle without opening the full length door.

5. Each load interrupter switch shall have the following features:

   - Three-pole gang operated
   - Manual quick-make/quick-break over-toggle-type mechanism that does not require the use of a chain or cable for operation, and utilizes a heavy duty coil spring to provide opening and closing energy
   - The speed of opening and closing the switch shall be independent of the operator, and it shall be impossible to tease the switch into any intermediate position under normal operation.
   - Separate main and break contacts to provide maximum endurance for fault close and load interrupting duty
   - Insulating barriers between each phase and between the outer phases and the enclosure
   - A maintenance provision for slow closing the switch to check switch blade engagement and slow opening the switch to check operation of the arc interrupting contacts.

6. Cables shall enter through bottom of switch except the two (2) switches that are directly coupled to transformers.

7. Wiring and Terminations

   - One (1) terminal pad per phase shall be provided for attaching contractor-supplied cable terminal lugs for a maximum of two (2) conductors per phase of the sizes indicated on the drawings. Sufficient space shall be supplied for contractor supplied electrical stress relief termination devices (G&W Electric Company Capnut Porcelain Terminations for 3/Conductor #4/0 15kV shielded PILC cables).
   - Small wiring, fuse blocks and terminal blocks within the vertical section shall be furnished as indicated on the drawings. Each control wire shall be labeled with

wire markers. Terminal blocks shall be provided for customer connections to other apparatus.

8. Fuses

- Fault protection shall be furnished by fuses as shown in the contract documents (see attached single-line diagram). The fuses shall have a minimum interrupting rating of 50kA symmetrical at 15 kV and shall be Cutler-Hammer or equal, current limiting type. Furnish three (3) spare fuses for each fused switch. Fuse/switch integrated momentary and fault close ratings specified shall have been verified by test.

9. Accessories

- Supply key interlocks as shown on the drawings.

i. Transformer Section

1. Transformer section shall consist of an open, ventilated Epoxy Cast Coil transformer with sheet metal enclosure and screened opening for ventilation. The transformer is totally encased epoxy cast primary and secondary coil.

2. Transformer shall conform to requirements in NEMA Standard Publication No. TRI-1980, ANSI/IEEE C.57.12.01-1979 and NEC Code as applicable.

3. The transformer shall be self cooled, type AA , ventilated epoxy cast coil and shall have a continuous rating of 2,000/2,667 KVA as specified.

4. The electrical insulation system shall utilize class H material in a fully rated 220 degree C system. Transformer design temperature rise shall be based on a 30 degrees C average ambient over a 24-hour period with a maximum of 40 degrees C. Solid insulation in the transformer shall consist of inorganic materials such as porcelain, glass fiber, electrical grade glass polyester, or Nomex. All insulating materials must be rated for continuous 220 degree C duty. The insulation between the high-and low-voltage coils shall be more than sufficient for the voltage stress without the need of a varnish.

5. The transformers shall be designed for a temperature rise of 115 degrees C and shall be capable of operating at 15 % above base nameplate kVA capacity continuously without any loss of life.

6. High voltage primary windings shall be copper, three phase, 60 hertz, 13,800 volts nominal, delta connected, suitable for use on effectively grounded system. High voltage winding insulation class shall be 15 KV, rated for basic impulse level (BIL) of 95 KV, minimum, and a low voltage (BIL) rating of 10 KV. The BIL ratings shall be achieved without the use of lightning (surge) arresters.

7. The transformers shall be designed to meet the sound level standards for dry-type transformers as defined in NEMA TR1.

8. Four 2 1/2 percent no load full capacity taps shall be provided in the high voltage winding: two above and two below the rated primary voltage.

9. Low voltage winding shall be of copper, three phase, 60 hertz, 480/277 volts nominal, wye connected, for 3 phase, 4 wire service. Low voltage insulation class shall be 1.2 KV minimum.

10. Impedance shall be 5.75% per unit on the transformer KVA base, +/- 7.5%.

11. Core and coil assembly shall be mounted on pads to isolate vibration from the structure. Core laminations shall be of non-aging, highly permeable, cold rolled silicon steel. The core and coil assembly shall be ruggedly constructed to prevent displacement and distortion under all normal conditions of handling and during operation under short circuit conditions.

12. Transformer primary shall be field connected to the load side of the interrupter switch either by bus or cable. Low voltage windings shall be factory wired to the secondary main breaker in the low voltage distribution under all normal conditions of handling and during operation under short circuit conditions.

13. A winding hot spot temperature indicator and relay (s) with two-step temperature settings and electrically independent contacts which close with rising temperature for alarm (first step) and tripping (second step) shall be provided. Scale shall be in degrees Celsius. Contacts shall be factory-wired to readily accessible terminal block for field connection to Station Annunciator, and the main circuit breaker. Device 49T and 49TH.

14. Transformer shall be tested in accordance with ANSI/IEEE C57.12.91.

15. The transformers shall be UL labeled.

16. The transformers shall be of explosion-resistant, fire-resistant, air-insulated, dry-type construction, and cooled by the natural circulation of air through the windings.

17. High-voltage and low-voltage windings shall be copper. Insulation between layers of the windings shall be by "Insuldur" paper or equal.

18. The transformers shall be supplied in a knockdown case design, for ease in fitting through limited openings, and shall be of heavy gauge sheet steel construction, equipped with removable panels for access to the core and coils. Front and rear panels shall incorporate ventilating grills.

19. Details of Transformer Section

Each Transformer Section shall consist of the following:

- Transformer temperature controller shall be equipped with three (3) high accuracy thermal type temperature sensors; one installed in an air duct in each phase coil of the transformer. The controller shall also have control sequencing to operate cooling fans (if used) and to alarm temperature sensors. First level of switching is to automatically turn fans on and off. The second level would energize an audible alarm and send trouble alarm to the SCADA. Third level would cause an emergency shutdown to drop the transformer load and send alarm to the SCADA system.

- All cubicles shall have hinged doors front and rear that are easily removed from the gear frame work, hinged on one side and bolted on the other and have the capability to be locked with a padlock.

C. Low Voltage Section

1. Low voltage section shall consist of 480/277 volt ac, metal enclosed, drawout type, indoor switchgear consisting of the following units.

   a. Transformer No. 1 secondary main circuit breaker and its control and instrumentation unit.

   b. Bus No. 1 feeder breaker units

   c. Bus tie circuit breaker, its control and instrumentation unit.

   d. Bus No. 2 feeder breaker units.

   e. Transformer No. 2 secondary main circuit breaker and its control and instrumentation unit.

2. The low voltage section shall consist of three basic compartments from front to rear: the front breaker compartment, the center bus compartment, and the rear cable compartment. The front breaker compartment shall contain the drawout circuit breaker (non-bolt-on type) elements, each mounted in its own barriered cell having a hinged door and handle with key lock and an external trip button. Active or future use cells equipped to accept circuit breakers shall be complete with the circuit breaker drawout mechanism and all current-carrying parts. The center bus compartment shall contain the section and main bus and isolated neutral bus. Size of the rear cable compartment shall accommodate all incoming and outgoing cables required within each vertical switchboard section. This compartment shall also contain the runback which is extended into this compartment from the bus compartment and a ground bus bolted directly to the switchgear frame. A neutral stud shall be extended into the cable compartment in each vertical section for connection of neutral conductors. Provide lugs for neutral and ground connection for each breaker and a bus connection for connecting the neutral to the ground bus with a removable isolating link.

3. Each main, bus tie and feeder circuit breaker compartments and instrument compartment shall be provided with a steel door having concealed hinges and hand operated latching device. Tools shall not be required to open or close the doors. The potential transformers and current limiting fuses shall be rigidly mounted in compartments provided with a hinged door for easy access. Each vertical section shall be provided with hinged sheet steel doors at the rear. Hinges shall be of heavy duty type. Doors shall be provided with stops to hold them securely in the open position and provision for padlocking in open position.

4. The stationary elements of switchgear shall include copper buses, copper connections, instrument transformers, the stationary portion manually operated mechanism for moving the circuit breaker to and from the connected position, terminal blocks and wiring for control and secondary connections. The removal element of switchgear shall consist of circuit breaker, the removal portion of the disconnecting devices, the operating mechanism and mechanical interlocks. The stationary structure shall be so constructed that each circuit breaker unit shall be interchangeable with every other unit of similar rating.

5. Buses: Main bus, bus taps and run-back buses shall be of high conductivity rectangular copper with rounded edges, mounted on supports of high impact non-tracking insulating material. Buses shall be braced to withstand short circuit stresses in the system. Buses shall be designed to carry rated current continuously without exceeding the hottest-spot temperature rise of 65 degrees C above building ambient of 40 degrees C. All bus taps and connections shall be tightly bolted with a

minimum of four 1/2 - 13 bolts. Contact surfaces of bolted joints shall be silver plated. Buses shall be provided in accordance with the following:

a. Main bus shall be 3 phase, 4 wire, having a continuous current rating less than 3,200 amperes, with a 100 percent rated neutral insulated from the structure.

b. Vertical riser buses shall extend from main bus to bus side terminals of feeder circuit breakers. Riser buses shall be properly sized for the breakers connected.

c. Buses shall be phased 1-2-3 left-to-right, top-to-bottom and front-to-rear, as viewed from the front of unit substation.

d. Run-back buses from feeder breaker load terminals shall be extended through the isolating barrier to the cable compartment. Similar provisions shall be made for spaces equipped for future circuit breakers.

e. Insulating barrier: An insulated, removable barrier shall be provided to isolate the main and riser buses from the cable compartment.

6. Main and bus tie circuit breaker shall be 3-pole, drawout type power circuit breaker with solid state programmer conforming to ANSI C37.13, C37.16 and C37.17 having the following ratings and accessories. The two main breakers and the tie breaker shall be electrically and manually operated and shall be interchangeable.

a. Ratings.

Rated voltage:	600 V
Frame size:	3,200 A
Current Sensor Rating:	3,200 A
Rating plug:	3,200 A (for 2,000 KVA transformer)
Current setting:	Adjustable in smooth
(Multiple of Rating	steps between 0.5 to
plug Amps)	1.1

b. Operating mechanism: Stored energy type, suitable for operation from a 120 Volts AC supply and shall be electrically and mechanically trip free. Operating circuits shall successfully close the breaker over a voltage range of 90 to 130 volts and trip the breaker over a voltage range of 70 to 140 volts. The breaker shall be designed so that they may be tripped manually in an emergency. A removable handle shall be provided for manual closing of the breaker for maintenance and adjustment. Control circuit shall be arranged to make the mechanism non-pumping, and shall have coils suitable for continuous operation. Closing relays shall be such that they may be used with either a momentary or maintained contact control station. Provisions shall be made for manually closing and tripping the breaker by mechanical means.

c. Disconnecting devices: Circuit breaker shall be equipped with the main and secondary circuit disconnecting devices to make the breaker and operating mechanism a removable element. The primary disconnecting devices consist of self aligned assemblies. Contacts shall be constructed of high quality material designed to insure high pressure contact guaranteed not to distort or fail under mechanical stresses and heating due to duties specified for circuit breakers. All contacts surfaces shall be heavily silver plated. The secondary disconnecting devices shall provide connections for the control circuits and interlocks between the removable element and the housing. The devices shall be accurately located and securely mounted to maintain alignment.

d. Drawout mechanism: Designed to move the breaker removable element from disconnected to test and connected position and shall overcome the mechanical resistance of making and breaking the contacts of the disconnecting devices. Positive mechanical interlocks shall be provided on the circuit breaker to prevent the withdrawal of the removable element when the breaker is in the closed position and to prevent the insertion of closed breakers from the test to the operating position. The interlocks shall also discharge the spring of the stored energy operating mechanisms before the breaker removable element can be fully withdrawn from its housing. Mechanism shall be arranged to permit the breaker to be racked from "connected" to "test" to "disconnected" position with the door closed. A positive stop shall be provided to prevent overtravel of the removable element when moving into the operating position. A similar stop shall be provided for the test position.

e. Series trip device: Solid state type, equipped, as a minimum, with adjustable long-time pickup (fixed at 1.0 of current setting) and time delay; short-time pickup and time delay; adjustable instantaneous pickup; adjustable ground fault pickup and time delay functions including neutral transformer for three phase, four wire, grounded system.

f. A mechanical indicator shall be provided to show whether the breaker is in the open or closed position. The indicator shall be visible from outside the compartment with the compartment door closed and latched.

g. Target indicator shall be provided to indicate the tripping mode-overload, short circuit or ground fault.

h. In addition to auxiliary switches required for control, interlock, indication and alarm circuits, each circuit breaker shall be furnished with a minimum of four "a" and four "b" spare auxiliary switch contacts, wired to outgoing wiring terminal block for Authority's use. The contacts shall be easily convertible in field.

i. All auxiliary switches, whether cell mounted or mounted on removable element, and breaker control circuit wiring connected through secondary disconnecting devices shall be made up and operable when breaker is racked to the test position so that the breaker may be closed and tripped electrically or mechanically with primary disconnecting devices open.

j. Normally closed auxiliary switches mounted on removable elements and used for interlocking shall be shunted with carriage-operated cell switches to permit operation of interlocked equipment when breaker is in the withdrawn or test position.

k. Two (2) future compartments (on both sides of the tie-breaker) for future breakers shall be completely equipped for the future addition of circuit breakers including all necessary electrical connections. Insulated boots shall be furnished on all exposed bus stabs in any unused breaker compartments.

l. All cubicles shall have hinged doors front and rear, hinged on one side and bolted on the other and have the capability to be locked with a padlock.

m. All draw-out breakers shall have local indications with manual reset switches for instantaneous, short-time, long-time, and ground fault.

n. Provide voltmeter, amp meter, with selector switches, and a utility grade kilowatt hour meter. These devices shall be located on the line side of both main secondary circuit breakers.

o. Provide the following safety devices for each main to be incorporated with the tie breaker transfer scheme:

1. 27 device - undervoltage

2. 47 device - phase sequence

3. 49 device - transformer thermal relay

4. 86 device - lockout relay

7. Branch circuit breakers shall be 3-pole draw-out type power circuit breakers with solid state programmer conforming to ANSI C37.13, C37.16 and C37.17 having the following ratings and accessories.

a. Ratings

Rated voltage:	600 V
Frame size:	Refer to one line
Current Sensor Rating:	Refer to one line
Rating plug:	Refer to one line
Current setting: (Multiple of Rating plug Amps)	Adjustable in smooth steps between 0.5 to 1.1

b. All other applicable requirements specified for main and bus tie breakers specified above are applicable for the branch breakers as well.

8. Transformers

a. Instrument transformers shall be of the dry type. Current transformers shall have 5 ampere secondaries. Rating of the instrument transformers shall be as specified herein. Potential transformers shall be rated 480-120 volts. Suitable current limiting fuses shall be provided for the primaries and non-renewable cartridge type fuses for the secondaries. A total of six spare current limiting fuses and 12 spare cartridge type fuses shall be furnished.

b. Potential transformers equipped with current limiting primary fuses shall be mounted on drawout or tilt out carriage. Design the front of the carriage to close the section when the transformers are in the operating position. Design primary contacts for the draw-out feature to ensure continuous positive contact pressure. Furnish carriages of sufficiently rigid design to maintain proper alignment of the primary contacts. Provide visible grounding devices to make certain that the draw-out carriage mounted potential transformer primary terminals are grounded when the carriage is withdrawn.

c. Fuse all ungrounded conductors of potential transformer secondary circuits. Provide fuses of the dual element cartridge type rated 20 amperes, 250 volts, mounted in barrier type porcelain base fuse holders. All instrument wiring to be copper fully insulated.

d. Ground the frames and cases of the potential transformers. The common secondary conductor of the potential transformers shall be grounded to the switchgear ground bus. Make the grounding of the potential transformers and the carriage to the switchgear ground bus by means of an extra flexible grounding strap. Make all grounding conductors as short as possible. Use continuous ground wires without splices or intermediate connections.

Install the case ground wires separate from the ground connections to the instrument transformer secondary wiring.

9. A two wire, grounded, alternating current, 120 volt No. 6 AWG control bus shall be provided throughout switchgear lineup insulated for 600 volt ac service. Supply shall be wired to suitable screw type terminal blocks located in the bus tie breaker vertical AC section for connection of ac supply cables entering from the top. Each breaker control AC circuit shall be supplied from this ac bus through fusible pullout disconnects with cartridge type fuses suitably rated located in each compartment. In addition, each circuit breaker close circuit shall be provided with a secondary set of fuses to prevent blowing of main fuses (and loss of trip ability) on closing faults. The fuse holders and fuses shall be rated 250 volts. All necessary fuses shall be furnished with the equipment. In addition, a minimum of 10 percent (but not less than two) spare fuses of each rating shall be furnished.

10. Each separated vertical section within a switchgear lineup shall be provided with an electric strip heater of adequate size to prevent condensation within the section. All heaters installed in the switchgear shall be monitored by means of an ammeter scaled for the heater load. Heater shall be provided with properly designed guards to protect operating personnel with accidental contact with hot surfaces. Space heater circuits shall be wired to terminal block in the tie breaker section for connection of (120 volt single phase ac) No. 12 AWG cable entering from above.

11. The switchgear control and operation shall be designed to comply with the Article 2.01-C: Proposed Control and Supervision.

12. Protective Device Coordination shall conform to requirements specified in Article 2.01-D: Protective Device Coordination.

13. All other devices required and/or shown on the sketches or required to achieve intended operation as specified shall conform to requirements if specified in this Section of to the best industry practice.

14. Details of Equipment

    a. Secondary Main Circuit Breaker and Instrument and Control Unit for 2,000 KVA transformer substation.

    Each unit shall consist of the following:

    - One vertical switchgear unit equipped with 3,200 ampere bus, arranged for connection to incoming buses for phase and neutral entering from the transformer section.

    One circuit breaker compartment equipped with the following:

    - One 3,200 ampere, 600 volt drawout circuit breaker.
    - Three current transformers, 3,200 ampere, for indication, ANSI accuracy class C200.
    - Two set of ac control power disconnect devices and fuses.

    One instrument compartment equipped with:

    - Two interposing relays, to close and trip the circuit breaker via supervisory, (Devices 201C and 201T).

- One control switch "TRIP-CLOSE" for closing and tripping the main circuit breaker in the operating and test positions, with green, white and red indicating lights (Device 1).

- One phase sequence and undervoltage relay.

- One multi-contact auxiliary relay for automatic transfer scheme, hand reset type, 120 Volt AC, (Device 47X).

- Two potential transformers, 480-120 volts, with primary current limiting fuses connected to line side of circuit breaker, open delta primary, grounded open delta secondary. Secondary also wired to terminal for external wiring.

- One indicating voltmeter, transformer rated, 0-750 volt scale.

- One Voltmeter switch, 4-position "OFF-AB-BC-CA".

- One indicating ammeter, transformer rated, 0-2,000-ampere scale.

- One ammeter transfer switch, 4-position, "OFF-A-B-C", center-of-circuit type.

- Lockout relay, manually reset type.

b. Bus Tie Circuit Breaker and Instrument and Control Unit for 2,000 KVA transformer substation.

The Unit shall consist of the following:

- One vertical switchgear unit equipped with 3,200 ampere bus for bus tie circuit breaker entering from the branch breaker units on the left and right of the unit. Also equipped with space heater and guard. Space heater shall have on/off switch with blue indicating light.

One circuit breaker compartment equipped with the following:

- One 3,200 ampere, 480 volt drawout air circuit breaker with 3,200 ampere sensor and 3,200 ampere rating plug.

- Two sets of AC control power disconnect devices with fuses.

One instrumentation compartment, equipped with the following:

- One control switch, "TRIP CLOSE" for closing and tripping the tie circuit breaker in the operating and test positions, with green, white and red indicating lights (Device 1).

- One circuit breaker control mode selector switch "LOCAL-OFF-SUPV" (Device 43).

- One two position selector switch for selection of mode of operation of 600 volt system - automatic transfer or manual transfer, AUTO-MANUAL.

- Two interposing relays, to close and trip the circuit breaker via supervisory.
- Two sets of AC control power disconnect devices with fuses for incoming AC circuit.
- One ammeter with indicating lights for space heaters.
- One set of auxiliary power disconnect devices with fuses for 120/208 incoming circuit.

c. Branch Circuit Breaker Unit consisting of the following:

- One vertical switchgear unit equipped with main bus of same size as the main or bus tie breaker to which it is attached and appropriately sized bus taps to breakers and runback buses with cable lugs from each branch circuit breaker.
- Space heaters with guards.

d. Bus transition unit forming vertical unit of the switchgear.

e. Circuit breaker test cabinet as specified.

f. Hydraulic Piston lifting device and mobile transfer truck and overhead lifting crane as specified.

g. Tools and Accessories - Following accessories shall be provided and shipped with the unit substation:

- A set of all special tools required for the erection, operation and maintained of all equipment.
- A removable hand crank for moving the circuit breakers to operating position (if required).
- A set of special wrenches for the primary disconnecting devices of the circuit breaker and other special purposes.
- A portable test set for testing the solid state protective devices during installation and maintenance.

2.03 CAPNUT TERMINATIONS

A. Capnut terminations shall be high grade, wet process porcelain for terminating paper insulated lead-jacketed (PILC) three conductor (3/C) copper # 4/0 AWG 15kV shielded cable with a low-smoke, halogen-free polymeric outer jacket. Terminations shall be cast body of non-ferrous material.

B. Terminations shall be bracket or flange mounted. Contractor shall determine method of support based on field observation of new medium voltage (15kV) load break switches.

C. Terminations shall be for indoor equipment application.

D. Contractor shall determine terminations body shape based on cable training required within the confines of the 15kV load break switches.

E. Contractor shall provide lugs, entrance fittings, and connectors as required.

F. Contractor shall provide mounting devices to support terminations.

G. Terminations shall be field assembled as required for cable type and terminating conditions to equipment. Assembly shall include, but not limited to, stress relief cones kits, insulating tape, shielding braid, and internal insulating compound of high dielectric oil-insoluble, non-migrating type.

H. Terminations shall be designed and tested in accordance with IEEE-48 standards for Class 1 terminations.

I. Terminations shall be for service on 15kV three conductor (3/C) cable system. The terminations shall have a BIL rating of 110kV. The current rating shall be the same as cable (# 4/0 15kV, 3/C) rating.

1 Minute Dry AC	50kV
6 Hour Dry AC	35kV
10 Sec Wet AC	45kV

J. Manufacturer shall be G&W Electric Company or equal.

PART 3 - EXECUTION

3.01 GENERAL

A. Install wire and connect unit substations complete and ready for operation in accordance with these Specifications, the manufacturer's instructions, and as shown on the Contract Drawings.

3.02 INSTALLATION

A. Contractor shall provide all hardware for mounting Capnut Porcelain Terminations within those Switches requiring such Terminations. Reference shall be made to Contract drawings (see single-line diagram).

3.02 CONDUIT AND WIRING WORK

A. Section 16050

1. Basic Materials and Methods for Electrical Work of the MBTA Standard Specifications - Construction shall apply.

3.03 GROUNDING

A. Section 16450

1. Grounding of the MBTA Standard Specifications - Construction shall apply.

3.04 DOUBLE ENDED UNIT SUBSTATION INSTALLATION

A. Install switchgear in the locations as shown on the Contract Drawings, secure, plumb and level and in true alignment with related adjoining work.

B. Provided anchor bolts and anchorage items where required and field check to insure proper alignment and location. Provide templates, layout drawings, and supervision at the job-site to insure correct placing of anchorage items in concrete. Check embedded items for correctness of location and detail before concrete is placed.

C. Provide supporting members, fastenings, framing, hangers, bracing, brackets, straps, bolts, angles, as required to set and rigidly connect the work.

D. Provide temporary bracing, guys, or other devices as required to accomplish erection and to provide safety and stability until all work is in final position completed and approved.

E. Control erection tolerance requirements so as not to impair the strength, safety, serviceability, or appearance as approved by the Engineer.

F. Exercise special care during construction to avoid overloading any part of the structure. Repair or replace any item damaged due to overloading to the satisfaction of the Engineer, at no additional cost to the Authority.

G. Align mismatched holes by reaming or replacing of clip connectors. Cutting with torches will not be permitted.

H. The Contractor shall furnish, install and connect 277/480 volts power cables between the switchgear and the substation building panel; 120 Volt AC control power supply cables between the switchgear and AC distribution panel or self contained in the unit sub-station; control, relaying and interlocking circuit cables; grounding cables; and all other wiring necessary for intended operation of the circuit breakers as specified herein and as shown on Contract Plans.

I. After completion of switchgear installation, the Contractor shall ensure that all doors and the drawout fuse and PT carriages operate freely and the breaker removable elements can be moved into and removed from the housings. Contractor shall correct all misalignments to the satisfaction of the Engineer. Contractor shall ensure all mechanical safety interlocks are operating properly. The completed installation shall be tested and checked out in accordance with approved procedure.

3.05 TESTS

A. General

1. All equipment to be furnished and installed shall be subject to the following test program. Testing shall include tests at a manufacturer's facility and in the field.

2. The Contractor shall formulate overall test program of the equipment which shall include but not be limited to the tests specified in this Section to ensure equipment compliance with the relevant standards, this Specification and satisfactory and reliable performance in intended operation.

3. Tests at the factory shall include but not be limited to:

   a. Manufacturer's standard tests.

   b. Tests as listed in Article 3.05.C, this Section.

   c. Tests as per relevant NEMA, IEEE and ANSI Standards not included in Article 3.05.C.

   d. Any other tests to ensure satisfactory performance of equipment.

4. Tests in the field shall include but not be limited to:

   a. Tests as listed in Article 3.05.D, this Section.

   b. Tests as per relevant NEMA, IEEE and ANSI Standards not included in Article 3.05.D, this Section.

   c. Any other tests to ensure satisfactory performance of equipment.

5. The Contractor shall meet the requirements in Article 3.03.B, this Section, for testing and shall furnish test reports as specified in Article 3.03.E of this Section for obtaining clearance for packing and shipment of equipment tested.

B. Conditions for Tests

1. General Conditions:

   Prior to testing of any equipment specified in this Section, all of the following conditions shall be fulfilled by the Contractor:

   a. Contractor has made the "For Record" submittal of shop drawings of the equipment scheduled for testing to the Engineer. Please note that "For Record" submittal shall be made only after the previous submittal has been approved by the Engineer.

   b. The Contractor-prepared test procedure has been approved by the Engineer.

   c. A minimum of four weeks advance notification shall be given to Engineer on the scheduled date of tests to enable them to witness the same.

2. Witnessing Tests:

   a. Engineer will witness complete testing of all equipment unless a waiver is granted, in which case test reports of equipment for which waiver was granted, shall be submitted for review to obtain clearance for packing and shipping.

   b. Waiver of witnessing tests on any one equipment shall not be constructed as a waiver for all remaining equipment either of the same type or different type.

3. Responsibility

   a. The Contractor shall assume full responsibility during the factory and field testing of all equipment and installation provided by him. Should there be any loss or damage to such equipment, materials or the building as result of these tests, the Contractor shall be fully responsible for replacing the damaged equipment and repairing the building. Replacement of damaged equipment shall include all costs including but not limited to, transportation of, and installation of replacement equipment.

4. Rejection and Retesting

   a. Failure of equipment to withstand tests or to meet ratings shall be sufficient grounds for rejection of equipment.

b. Any equipment rejected shall be retested in presence of the Engineer, or his representative, after rectification. If the modifications or changes are such as to affect any of the drawings, diagrams or any other documents submitted and accepted by the Engineer, revised drawings or diagrams shall be submitted, showing proposed changes and Engineer's approval obtained before changes or modifications are made on the equipment. Modifications or changes which do not warrant revision of any drawing, shall be furnished to the Engineer along with notice of retesting.

c. If it is not possible to rectify rejected equipment, new equipment shall be manufactured and the requirements of the drawings and design calculations of the original unit shall be applicable for the new unit.

5. Cost of Rectification or New Unit

a. The entire cost of rectification or new unit shall be borne by the Contractor including retesting and cost of witnessing retesting.

6. Cost of Tests

a. The price of conducting all factory and field tests and checkouts in presence of the Engineer, or his representative, including entire cost of rectification, retesting and supplying new unit (s), shall be deemed to be included in the Contract Price. The expenses related to travel, lodging and boarding for the Engineer and/or his representative for witnessing of tests will, however, be borne by the Authority at no expense to the Contractor, except when retesting is required. In the latter case, all expenses for travel, lodging, meals and hourly payroll costs including overhead and fringe benefits for the Engineer and/or his representative will be borne by the Contractor as directed by the Engineer.

C. Factory Tests

1. Double Ended Unit Substation Assembly

a. Following tests listed in ANSI C37.20 as "Production" test shall be conducted at the manufacturer's facility on the Double Ended Station assembly.

1). Power frequency dielectric tests
2). Mechanical operation tests
3). Grounding of instrument transformer cases test
4). Electrical operation and control wiring tests
- Control wiring continuity test
- Control wiring insulation test
- Sequence tests
- Polarity tests

b. Contractor shall submit copies of "Design Tests" report conducted on similar assembly.

2. 13.8 KV Section

a. Metering circuit functional and polarity checks.

b. Door alignment and breaker interchangeability check.

c. High potential test of primary and secondary circuits.

d. Switch mechanism and manual operation inspection checks.

e. Switch pole resistivity measurements.

3. Air Interrupter Switches

a. The manufacturer shall submit the certificate of design tests conducted on an identical air interrupter switch for Engineer's approval.

b. The manufacturer's standard production tests shall be conducted in the presence of the Engineer.

4. Epoxy Cast Coil Transformers

a. Following tests shall be conducted at the manufacturer's facility on each transformer. These tests shall be conducted as described in ANSI C57.12.91 and/or ANSI C57.12.01.

- Resistance measurements
- Ratio tests
- Polarity and phase relating tests
- Excitation loss
- Excitation current
- Excitation and load loss
- Low-frequency dielectric tests:
  - Applied potential test
  - Induced potential test
- Audible sound test

b. In addition, manufacturer's test certificate for the following tests specified as optional tests in ANSI C57.12.01 and/or ANSI C57.12.91 and/or NEMA ST20 conducted on a similar transformer shall be furnished:

- Temperature tests
- Impulse tests (not required for 480-208/120V transformers)
- Insulation power factor tests
- Short circuit test

5. Power Circuit Breakers - Following tests listed in ANSI C37.50 as "Production Tests" shall be conducted at the manufacturer's facility on each and every 600 Volt power circuit breaker to be furnished in this Contract.

Calibrated tests:

- Direct acting trip devices
- Undervoltage trip devices
- Control, secondary wiring and devices check
- AC dielectric-withstand test
- No-load operation test
- All manufacturer's standard tests which are not covered in the above listed production tests.

In addition, manufacturer shall furnish test certificates for all the tests listed in ANSI C37.50 as "Design Tests" conducted on similar 600 volt power circuit breaker.

6. Relays

a. Following tests as listed in ANSI C37.90 shall be conducted on all the relays.

- Test for operation at minimum voltage.
- Dielectric tests.

7. Auxiliary Equipment and Components

a. Tests on auxiliary equipment and components shall be conducted as required by relevant ANSI, IEEE, NEMA and UL Standards in accordance with the manufacturer's standard testing procedure.

D. Field Tests

1. General

a. All substation equipment will be subject to a field performance test. This test shall be performed by a qualified independent testing company and witnessed by MBTA personnel from the Power Systems and Equipment Area. This independent test company cannot be associated with the manufacturer of the supplied substation equipment. Field tests are to be performed to supplement the factory tests and to ensure proper operation of equipment and proper calibration and coordination of protective devices. Contractor shall furnish and set up all specified equipment required for these tests. All work should be performed using the applicable guidelines of the National Electrical Testing Association (NETA) Acceptance Specification.

b. The work includes furnishing of labor, material, test instruments and services necessary to perform required testing and checking of electrical equipment and installation.

c. All tests shall be successfully completed to show that the installation meets the specification requirements and that the equipment and devices operate as intended, before final acceptance by the Authority.

d. Tests and checkouts shall be conducted in accordance with the Engineer's approved test procedure specified herein and in National Electric Code, Massachusetts State Electrical Code and applicable Standards and Specifications of ANSI, NEMA, ICEA, AEIC, etc.

e. Contractor shall provide properly qualified personnel who shall be responsible for supervising, coordinating, and performing all electrical field testing and checking work and who maintains a written record of all tests conducted.

f. Testing and checkouts shall be performed in the presence of the Engineer.

g. Contractor shall furnish four copies of all test results to the Engineer. Results sheets shall include date of test, personnel involved, items tested, type of tests and test data.

h. Any equipment of material damaged due to improper test procedure or test apparatus handling shall be replaced or restored to original condition by Contractor at his expense.

i. Safety devices including but not limited to rubber gloves and blankets, screens and barriers, danger signs, padlocks, etc., shall be used to protect and warn all personnel in the vicinity of the tests.

j. All test instruments used shall have a certified calibration sticker showing last date of calibration and expiration date.

2. Field Test Requirements

a. Contractor shall formulate a complete Field Test procedure for equipment to be furnished and installed. Test procedure shall be comprehensive and shall include the required tests as specified in relevant standards of ANSI, NEMA and IEEE, supplementing the Factory Test procedure.

b. The Contractor shall submit the test procedure to the Engineer for review and approval well in advance to the commencement of field tests. Engineer reserves the right to add, delete or make necessary changes in the test procedure. The Contractor shall arrange the conduct of all the field tests as per the Engineer approved procedure. Since the Contractor is responsible for the performance and installation of the equipment furnished under this Section, he shall, therefore, prior to testing verify that the installation is proper and in accordance with all applicable installation instructions specified herein.

c. Load Break Switches:

1. Cubicle heater operation
2. Motor operation
3. Calibrate and function test all relay devices.
4. Check hardware, indicator lights, and insulators. (torque if necessary)
5. Kirk key evaluation.
6. Blade and arc chute operation.
7. Power factor lighting (surge) arresters. (if available).
8. Dielectric tests. (Insulation and contact resistance)
9. High potential tests. (Hi-pot)

d. Transformers:

1. Double power factor excitation test with 10 KV tester.
2. Hi-pot primary side.
3. Meggar secondary side.
4. Transformer turns ratio (TTR) test.
5. Core ground test.
6. Insulation resistance test.
7. Test cubicle heaters.
8. Check all hardware, bushings and vibration mats.
9. Visual and mechanical inspection.
10. Test temperature control panel and verify alarm stages.
11. Clean transformer.

e. 480 Volt Switchgear

1. Primary injection test of all breakers through all settings.
2. Secondary injection test using the integral test panel trip unit through all the settings.
3. Check and verify cell code types.
4. Visual and mechanical inspection of all breakers.
5. Insulation resistance test on all phases to all breakers.
6. Dielectric tests on all 480 Volt buses.
7. Test all relays and 47 devices with three phase power source.

8. Test all meters. (KWH, volt, ampere, and heater)
9. Test all cubicle heaters.
10. Evaluate Kirk key system
11. Test total operation of main breakers to tie breaker transfer schemes.

f. Equipment and Instruments

1. Check alignment and proper operation of all equipment including operating mechanisms, clearances, adjustment of contacts, and accessory equipment.

2. Visually check each molded case circuit breaker and operate manually. For each breaker with adjustable magnetic trips, set trips, meggar each pole for freedom from grounds, and check for proper current rating for connected circuit.

3. Test indicating instruments, such as ammeters, voltmeters, and other instruments, by checking and adjusting pointers on zero scale with no load or voltage.

g. 600 Volt Wire and Cable

1. Test in accordance with Section 16120.

h. Control and Devices

1. All electrical controls shall be tested by trial operation of control equipment to verify that control circuits function as intended and are in agreement with manufacturer's instructions.

E. Tests Reports

1. The Contractor shall submit five certified copies of test reports for all the tests conducted at the factory and at field for Engineer's approval. Test reports shall be submitted to the Engineer within seven days after completion of tests. In case of "Design Tests" and tests on rectifier packages, test reports shall include original data, detailed calculation of test data used to arrive at the results and interpretation of results. Test reports shall contain the characteristics curves, etc., where required for interpretation of results.

2. Before equipment can be energized, all tests have to be performed and verified with a copy of all test results from the factory. Field performance tests and power system studies (such as short circuit coordination and evaluation study, protective device coordination and evaluation study, and ground grid test data) shall be submitted to the Power Systems and Equipment Group, to be reviewed and verified before equipment is energized.

3.06 CAPNUT TERMINATIONS

A. The 15kV splices and terminations shall be executed in strict compliance with the cable and terminations manufacturers' instructions. Terminations shall be filled with an approved insulating compound in accordance with manufacturer's instructions.

B. The entire length of new cable shall be fireproofed inside handholes, and termination equipment enclosures from the cables point of exit to its point of reentry into the conduit

C. Install the 3/C 15kV PILC cables as shown on the contract drawings.

D. Terminate the 3/C 15kV # 4/0 AWG PILC cables in terminations (potheads) located in the 15kV non-fused load break switches enclosures at the Maverick Station unit substation as shown on the contract drawings.

E. Ground cable sheath and individual cable shields at the unit substation 15kV non-fused load break switches only and not the fused transformer primary load break switches.

3.07 MANUFACTURER'S CERTIFICATION

A. A qualified factory-trained manufacturer's representative shall certify in writing that the equipment has been installed, adjusted and tested in accordance with the manufacturer's recommendations.

B. The Contractor shall provide three (3) copies of the manufacturer's representative's certification.

3.08 TRAINING

A. The Contractor shall provide a training session for up to 3 owner's representative for one (1) normal workday at a jobsite location determined by the owner for the completely assembled unit substation.

B. The training session shall be conducted by a manufacturer's qualified representative and consist of instruction on the assembly, switches and major components.

PART 4 - MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

No separate measurement shall be made for the Work of this Section.

4.02 PAYMENT

Payment for the Work in this Section shall be included as part of the payment items listed below.

4.03 PAYMENT ITEMS

ITEM No.	ITEM DESCRIPTION	UNIT
1623.001	Electric AC Unit Substation	LS

END OF SECTION

SECTION 16313

REMOTE TERMINAL UNIT

PART 1 - GENERAL

1.01 GENERAL

A. This Section specifies the furnishing and installation of remote terminal unit (RTU), for the purpose of supervisory control and data acquisition (SCADA), at the Unit Substation B2 and Ventilation Shaft B3. The Installation shall consist of a complete RTU and enclosure, as well as, a separate supervisory terminal board (STB) and enclosure that shall serve as an interface between the RTU and the field equipment.

1.02 RELATED WORK SPECIFIED ELSEWHERE

A. Section 16050, "BASIC MATERIALS AND METHODS"

B. Section 16311 and 16312, "DOUBLE ENDED UNIT SUBSTATION"

C. Section 16450, "GROUNDING"

D. Section 16920, "MOTOR CONTROL CENTERS and MOTOR STARTERS"

1.03 GENERAL REQUIREMENTS

A. Each RTU shall be integrated into the existing Micro/1C MBTA SCADA system manufactured by Valmet Automation of Houston, TX. The SCADA master terminal unit (MTU) consists of two redundant DEC VAX 4000/200 computers which execute Valmet Sage Series VII Power Distribution and Management software. The MTU polls all RTUs on a continuous basis to monitor the status of devices, such as circuit breakers, relays, transfer switches, and alarms as shown on the contract drawings and specified in other sections of these specifications. Scanning of a particular RTU is interrupted when a control command is sent to that station. RTU's shall conform to the Standard MBTA Specification P-168 "The Procurement of SCADA Remote Terminal Units in Unit Substations" copy of specifications is included at the end of this specification.

B. Communication between the MTU and the RTUs shall be via a new 25 pair shielded, 19 gauge communication cable from the Double-Ended Unit Substation RTU located at the Unit Substation B2 and Ventilation Shaft B3 to the new Maverick Station Communication Room is included as part of this contract. The route to 45 High Street shall be via a PCM channel on the PCM channel bank at the Maverick Communication Room. Frequency shift keying shall be used with Bell 202 type modems at each end (Ventilation Shafts and Communication Room). The protocol employed shall be the Valmet Sage Series V protocol. The units shall be able to operate with the existing MBTA Systemwide SCADA system and provide all of the capabilities that the current MBTA RTUs provide.

C. The furnished equipment shall be installed in Unit Substation B2 and Ventilation Shaft B3 at the locations shown on the Contract Drawings. The RTU system shall interface directly to the following equipment and systems as a minimum:
   1. Double-Ended Unit Substations B2 and Maverick Station

2. Ventilation Shafts (B5 and B3)
    - Motor Control Centers

1.04 SUBMITTALS

A. Submittals shall be in accordance with Section 01300 and Section 16050, except as modified herein.

B. Manufacturer's data shall be submitted for the following:

1. Detailed description and drawings of all equipment to be furnished and reliability data such as MTBF and MTTR.

2. Verification that the system is compatible with the existing Valmet Sage Series VII system.

3. List of previously installed units of similar nature.

4. Complete point-to-point wiring diagrams including terminal arrangements, wire number and routing between various sections of the cabinet.

5. RTU enclosure fabrication drawings indicating dimensioned layout of all components, terminals and auxiliary devices.

6. Catalog cuts for all components, devices including power supplies and I/O sections.

7. Testing: Submit testing program for Engineer's review and approval for confirmation of interoperability of all equipment and proper communication with the MTU.

8. Shop Tests
    a. Submit shop test reports for all devices.
    b. Submit shop test reports within 10 working days after test completion.

9. Field Test Reports
    a. Field test reports shall be submitted for each test within 10 working days after test completion.
    b. Field test reports shall be certified.

1.05 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Deliver, store, handle and install all materials and equipment in such a manner as not to degrade quality, serviceability or appearance.

B. Store materials in sewer and dry facility and in original packaging in a manner to prevent soiling, physical damage, wetting or corrosion before installation.

C. Replace damaged materials and equipment as determined by the Engineer at no additional cost to the Authority.

1.06 OPERATION AND MAINTENANCE MANUALS

A. Operation and maintenance manuals shall be furnished in accordance with Section 1700.

1.07 AS-BUILT DRAWINGS

A. As-built drawings shall be furnished in accordance with Section 1700.

1.08 WARRANTY

A. Warranty shall be provided in accordance with requirements of MBTA Standard Specifications P-168.

PART 2 - PRODUCTS

2.01 REMOTE TERMINAL UNITS

A. General: The function of the Remote Terminal Unit (RTU) shall be to process status input information and control output commands being communicated between the master terminal unit and the monitored field devices. It is expected that at a minimum the RTU shall be comprised of the following system components; an on-board central processing unit with 8 megabytes of Ram, a multi-port communication Interface with a 202T type modem, digital input and output cards, a system power supply, and a battery backup unit with charger. All systems components are to be housed within a wall mounted NEMA 12 enclosure.

B. Central Control Board

The central control board shall consist of thee following items:

1. A 16 bit, 8 Megahertz Central Processing Unit.
2. 8 Megabytes of Random Access Memory.
3. 512 kHz EEPROM to store system operating firmware.
4. System clock.

The processor shall be capable of:

1. Supporting RTU expansion up to 256 status inputs, 100 analogs, and 128 SBO relays.
2. Holding up to 256 time stamped system events in memory between normal MTU scans.
3. Maintaining sampling rate of 3 milli-seconds (ms) to ensure accurate time stamping of events.
4. Acting as a stand-alone unit to record all system events in case of a communication failure within the MTU for a period of up to 12 hours.

C. Power Supply

The RTU shall be fed from a house supplied 120-volt ac circuit. The RTU shall include an internally mounted power supply capable of providing the appropriate voltages and currents required by RTU equipment. In addition, the RTU shall have contacts to sense a loss of ac power, high dc voltage, and low dc voltage. Power supply shall provide low voltage dc for solid-state circuits, status field contact voltage, and control output relay coil voltage. Power supply is of the intelligent power supply / charger type.

D. Circuit Cards

All electrical components shall be mounted on modular and uniform sized circuit cards.

All cards shall be provided with heavily gold plated contact tips or connecting plugs, which shall mate with, approved sockets.

All cards and boards shall be made of fiberglass-reinforced epoxy sheets or equivalent. Materials such as paper phenolic are not acceptable. All holes in the cards shall be either plated-through or provided with eyelets to allow reliable solder joints.

To prevent corrosion all conductors on the cards shall be gold or tin-plated. No bare copper shall be exposed. In addition, all boards shall be dipped in a solderable moisture-proofing compound after all manufacturing procedures are completed.

One complete set of spare cards shall be furnished as technical support equipment for trouble shooting the system. One spare card shall be provided for each card installed in the RTU's.

All chassis shall be designed for flush mounting on other standard size relay racks or within cabinets providing similar mounting provisions.

If the cards are to be mounted within a card-supporting cage, access to all cards shall be provided by means of removal handles where a special tool for removal is not provided.

Cards shall be notched and/or keyed to prevent cards from being installed in the wrong socket. Un-keyed cards shall be accepted provided they are clearly labeled in accordance with their positions of insertion. Circuit card supporting chassis or framework shall provide guides for both the bottom and the top edges of their modular circuit cards.

In physical construction, each chassis shall conform to NEMA 12 standards for semi dust tight enclosures. All components of the chassis shall be 1/8 inch thick or heavier, except that formed or die stamped steel components may be a minimum of 16 gauge.

All aluminum chassis components shall have an approved protective coating. All steel chassis components shall be nickel plated or equal after drilling, notching, punching, etc.

Barrier type terminal blocks shall be furnished for all external connections. Terminal blocks shall be mounted within the cabinet enclosures and shall be easily accessible. Each block shall be provided with a strip that shall comply with wiring diagrams that are to be submitted for approval.

E. Digital (Status) Inputs

1. Number of DI points: Minimum of 60. See STB drawings and points list for actual points required. Provide 50 percent spare terminals.

2. All points optically isolated to withstand 1500 V dc.

3. Provide debounce circuits to prevent false readings due to electrical noise.

4. Field loops: Utilize 24 V dc.

5. Use modular DI boards accepting 16 connections via ribbon cable.

F. Digital Output (SBO): The operating modes for the control outputs shall be of the select check operate check, momentary type. Eight trip/close pairs (16 relays) shall be provided. These interposing relays shall have dust proof covers. The dwell time of the output relay shall be continuously adjustable from 10 milliseconds to 5 seconds. Relays shall be rated for 50 V dc, 5A and 240 V ac, and 10-amp operation, with a minimum of 2 Form C contacts. The RTU response time must not be delayed by the dwell time of the relay.

G. Analog Inputs

1. Analog input points: Minimum of sixteen required.

2. Analog values to be based on 0-5 V dc, differential type inputs.

3. Resolution: 13 bit (12 bits plus sign).

4. Common mode noise rejection: 85 dB at 100 volts peak to peak.
5. Normal mode noise rejection: 60 dB, 50 Hz or 60 Hz, 5 VP-P.

6. Resistance: 10 Megohm or greater between two channels.

H. Communication Interface

The system communication interface shall allow the unit to be scanned by the MTU on a continuous basis. This hardware shall consist of a minimum of two asynchronous ports. The primary port shall consist of a Bell 202T modem to receive the transmit FSK signals at speeds between 1200 and 9600 BPS. Light Emitting Diodes to indicate data receive, data transmit, request to send, clear to send, and error conditions shall be included.

Communication parameters such as baud rate, receiver gain, transmit output level, CTS delay and RTS delay shall be user-selectable through means of DIP switches or serial input from a lap top computer. The interface shall also be capable of transmitting and receiving data through an alternate medium such as licensed band frequency, wireless, or spread spectrum radio communication.

An RS-232 serial port shall also be included to serve as a user port for connection to a laptop PC used to configure the RTU or to run vendor supplied diagnostic software. Additional port may include ports to establish communication with another RTU in a remote/sub-master configuration or to interface with intelligent electronic devices that could be installed in the future.

Each RTU shall be equipped with a set of gas tubes that shall protect the inputs against voltage spikes of up to 1000 V dc.

1. Enclosure: RTU equipment shall be housed within a wall mounted NEMA 12 rated cabinet, with panels or stretcher leveled steel not less than no. 11 US Gauge (5.0 pounds per square foot), with integral supported framework. The interior shall be finished with baked white enamel. The exterior shall be primed and finished with ANSI 61 non-glare gray lacquer. All surfaces shall be phosphatized before painting.

J. Battery back-up: RTU shall have a battery back up unit that shall allow the RTU to operate for a minimum of 12 hours after the loss of primary power. The battery shall be a 24 volt sealed cell storage battery. The manufacturer shall recommend the voltage and ampere rating.

K. An intelligent power supply/battery charger module shall be furnished to provide a floating charge to the battery. The charger shall have a set of contacts that close when the charger fails or is shut down. These contacts shall be used for an indication of the charger status, "DC OK" and "AC OK" alarms, a battery test feature and regulated power for a radio. Modules shall also provide temperature compensated battery charging for optimum battery state.

Communication Protocols

The RTU shall be capable of interfacing with both synchronous and asynchronous protocols. In addition to any vendor supplied proprietary protocols, the RTU shall be capable of communicating with external equipment using DNP 3.0 or the emerging UCA-compliant MRP protocol.

M. Environmental: The RTU must be able to perform in a hostile environment that may include dust, moisture, electrical noise, and heat. The RTU shall be able to function properly in temperatures ranging between minus 40 degrees Celsius and plus 85 degrees Celsius and humidities ranging between 5 percent and 95 percent without the aid of a fan.

N. Reliability: All RTU components shall demonstrate a high degree of reliability in terms of mean time between failure (MTBF). The vendor shall provide all available data, concerning potential defects and repair time for all components to be used in the unit.

O. Maintainability: The manufacturer shall provide all equipment necessary to allow maintenance of the unit by reducing the mean time to repair (MTTAR) on the unit. Such equipment shall include a Valmet SmartSet test set, which shall be used as a diagnostic trouble shooting tool and a complete set of spare parts to be located on site so that defective parts may be replaced immediately. Spare parts shall be available within 48 hours from the time that the order is placed.

P. Cable Tags: Provide cable tags for communications cables with stamped letters and munbers identifying communication cable at each end near the respective terminal box. Install cable tags

at entry points of pull boxes, splice boxes, manholes, cable vaults and LDF. Use Ty-Rap fasteners to secure tag to cables.

Q. Conduit. Conduit shall be of the type used for power and lighting circuits as shown on the drawings, and shall conform to Section 16050. Conduit size shall be indicated on the drawings. Nylon or plastic pull wire shall be furnished for empty conduit runs.

2.02 SUPERVISORY TERMINAL BOARD {STB)

A. The installation shall include a Supervisory Terminal Board that shall serve as an interface between the RTU and the field equipment. All wiring for status, control, and analog points shall pass through the STB.

B. The STB shall consist of three columns of 50 barrier-type terminal blocks mounted on the back wall of a NEMA 12 cabinet. The cabinet shall be a wall mounted as shown on the Contract Drawings. The cabinet shall be easily accessible from the front and leave enough space for work to be performed within. There shall be terminal points available for all the station points with a minimum of 50 percent spare points. All termination points shall be fully labeled and clearly shown on drawn up wiring lists. A printed layout of the termination panel shall be posted on the inside of the hinged door of the enclosure. The layout shall be located in a fixed metal holder with clear protective cover. Laminated layout drawing is acceptable.

PART 3 - EXECUTION

3.01 GENERAL

A. The contractor shall furnish all the equipment and accessories specified herein, and all accessories and details not specifically mentioned or fully detailed but which is deemed necessary or which are reasonably required to make a complete and well integrated unit within the scope of this specification. The contractor shall furnish, before the completion of the equipment, a complete set of drawings for approval by the MBTA or MBTA-designated representative. The drawings shall include detailed wiring diagrams, relay data, operations and maintenance manuals, mechanical drawings, outlines and section views, bills of material, and construction details including weights.

B. The contractor shall provide a qualified technical representative to the MBTA to assist in the proper procedures for the correct installation, test, start up, trouble-shooting, maintenance, and checkout of the remote terminal units supplied under this contract. The technical representative must be fully qualified and experienced in supervisory systems and shall have the authority to represent and act for the supplier. The contractor shall carry costs for this representation for five workdays as directed by the MBTA.

C. If the furnished equipment is not Valmet Automation equipment, the contractor shall provide verification that a Valmet SmartSet test set can be used for trouble shooting purposes. The manufacturer shall provide auxiliary equipment that may be needed to interface the RTU to the test set.

D. All equipment shall be wired and connected to the RTU system as shown on the Contract Drawings.

Provide a 120V-ac circuit to the RTU power strip from the panel boards shown on the Contract drawings.

E The RTU system equipment shall be properly grounded in accordance with the manufacturer's recommendations and as specified in Section 16450.

F. All RTU system equipment shall be labeled and identified on the record drawings and Operation and Maintenance Manuals.

G. Perform functional testing in accordance with the proposed functional testing program as submitted and reviewed and approved by the Engineer. Submit functional testing program and certified test reports.

3.02 WARRANTY OF EQUIPMENT

A. All equipment furnished under the contract shall be guaranteed for one year from date of final acceptance. The warranty period shall begin at the time that the RTU is permanently integrated into the operating SCADA system and all software testing is completed.

B. During the guarantee period, any defective components or units, for which spare parts were provided to the MBTA shall be repaired or replaced within two weeks of receipt. Defective components or units, for which spare parts were not provided, shall be repaired or replaced within 48 hours after receipt of such.

3.03 FINAL ACCEPTANCE AND MAINTENANCE

A. Prior to final acceptance, technical assistance shall be provided as required at no cost to the Authority.

B. After the final acceptance and during the warranty period, the MBTA shall maintain the system. The Contractor / Manufacturer shall provide technical assistance during the warranty period. The Contractor / Manufacturer shall be reimbursed on a per diem basis for this technical assistance. If the defective components or units are the cause of the problem all costs associated with the technical representative (labor and expenses), replacement parts shall be considered as part of the warranty, and no reimbursement shall be provided.

PART 4 - MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement will be made for the work under this section but all costs shall be included for payment in the lump sum pay item TUNNEL VENTILATION SYSTEMS which will be paid for under a lump sum basis, complete in place including all testing, connections and incidentals as shown on the Drawings and as specified herein.

4.02 PAY ITEMS

ITEM NO.	DESCRIPTION	UNIT
1586.040	TUNNEL VENTILATION SYSTEMS	LS

END OF SECTION

MASSACHUSETTS
BAY
TRANSPORTATION
AUTHORITY

TRANSPORTATION SUPPORT SYSTEMS
POWER SYSTEMS & EQUIPMENT

JANUARY 22, 1997

SPECIFICATION P-168

THE PROCUREMENT OF SCADA REMOTE TERMINAL UNITS IN UNIT SUBSTATIONS

Specification for the Procurement of SCADA RTUs for M.B.T.A. Unit Substations

1.0 Scope

This specification covers the furnishing of remote terminal units (RTUs), for the purpose of supervisory control and data acquisition (SCADA), in the M.B.T.A. unit substations. The installation will consist of a complete RTU mounted in an enclosure as well as a separate supervisory terminal board (STB) and enclosure which will serve as an interface between the RTU and the field equipment.

2.0 Current M.B.T.A. SCADA System

The furnished RTUs will be integrated into current M.B.T.A. SCADA system which was provided by Valmet Automation of Houston, TX and installed by Union Switch and Signal of Pittsburgh, PA. The SCADA master terminal unit (MTU) consists of two redundant DEC VAX 4000/200 computers which execute Valmet Sage Series VII Power Distribution and Management software. The MTU polls all RTUs on a continuous basis to monitor the status of devices, such as circuit breakers, relays, transfer switches, and alarms. Scanning of a particular RTU is interrupted when a control command is sent to that station.

Communication between the MTU and the RTUs is done over wire telephone circuits using frequency shift keying. A Bell 202 type modem is used at each end. The protocol employed is the Valmet Sage Series V protocol. The provided units must be able to operate within this system and provide all of the capabilities that the current RTUs provide.

3.0 M.B.T.A. Unit Substations

The furnished equipment will be installed in the M.B.T.A.'s unit substations. Each unit substation receives 13.8 kV AC power, transforms it down to 480 volts AC, and distributes it to essential equipment, such as vent shaft fans, platform lights, escalator motors, heaters and signalling equipment. Most of these stations are located in areas that present severe environmental problems, such as extreme heat, electrical noise, copper and rail dust, moisture, and water leaks. All of these conditions should be considered during the design process and appropriate measures should be taken to guard against these potential problems.

4.0 Remote Terminal Unites

4.1 General The function of the Remote Terminal Unit (RTU) shall be to process status input information and control output commands being communicated between the master terminal unit and the monitored field devices. It is expected that a minimum the RTU will be comprised of the following system components; and on-board central processing unit with 8 megabytes of RAM, a multi-port communication interface with a 202T type modem, digital input and output cards, a system power supply, and a battery backup unit. All systems components are to be housed within a wall mounted, NEMA 4 enclosure.

4.2 Central Control Board

The central control board shall consist of the following items:

1. A 16 bit, 8 Megahertz Central Processing Unit
2. 8 Megabytes of Random Access Memory
3. 512 Khz EEPROM to store system operating firmware.
4. System clock

The processor shall be capable of:

1. Supporting RTU expansion up to 256 status inputs, 96 analogs, and 128 SBO relays.
2. Holding up to 256 time stamped system events in memory between normal MTU scans.
3. Maintaining sampling rate of 3 ms to ensure accurate time stamping of events.
4. Acting as a stand alone unit to record all system events in the event of a communication failure with the MTU for a period of up to 8 hours.

4.3 Power Supply. Each RTU will be fed from a house-supplied 120 Volt AC circuit. Therefore, each RTU should include an internally-mounted power supply able to provide the appropriate voltages and currents required by RTU equipment. Also, each RTU should have contacts to sense for a loss of AC power high DC voltage, and low DC voltage. Power supply shall provide low voltage DC for solid-state circuits, status field contact voltage, and control output relay coil voltage.

4.4 Circuit Cards. To the greatest extent practicable, all electrical components should be mounted on modular and uniform sized circuit cards.

All cards shall be provided with heavily gold plated contact tips or connecting plugs which shall mate with approved sockets.

All cards and boards shall be made of fiberglass-reinforced epoxy sheets or equivalent. Materials such as paper phenolic will not be accepted.

To ensure reliable solder joints, all holes in the cards shall be either plated-through or eyeletted.

To prevent corrosion all conductors on the cards shall be gold or tin plated. No bare copper shall be exposed. In addition, all boards shall be dipped in a solderable moisture-proofing compound after all manufacturing procedures are completed.

One complete set of additional cards will be furnished as technical support equipment for trouble-shooting the systems.

All chassis shall be designed for flush mounting on other standard size relay racks or within cabinets providing similar mounting provisions.

If the cards are to be mounted within a card-supporting cage, access to all cards shall be provided by means of removal handles where a special tool for removal is not

provided. Wherever possible, cards should be notched and keyed to prevent cards from being installed in the wrong socket. Unkeyed cards will be accepted provided they are clearly labeled in accordance with their positions of insertion. Circuit card-supporting chassis or framework shall provide guides for both the bottom and the top edges of their modular circuit cards.

In physical construction each chassis shall conform to NEMA 1A standards for semi-dust-tight enclosures. All components of the chassis shall be 1/8 inch thick or heavier, except that formed or die stamped steel components may be as light as 16 gauge.

All aluminum chassis components shall have an approved protective coating. All steel chassis components shall be nickel plated or equal after drilling, notching, punching, etc.

Barrier-type terminal blocks shall be furnished for all external connections. Said terminal blocks shall be mounted within the cabinet enclosures and shall be easily accessible. Each block shall be provided with a strip that shall comply with wiring diagrams that are to be submitted for approval.

4.5 Digital (Status) Inputs

1. No. of DI points: 48 for this application
2. All points optically- isolated to withstand 1500 VDC
3. Provide debounce circuits to prevent false readings due to electrical noise
4. Field loops: Utilize 24 VDC
5. Use modular DI boards accepting 16 connections via ribbon cable

4.6 Digital Output (SBO). The operating mode for the control outputs shall be of the select-check-operate-check, momentary type. Eight trip/close pairs (16 relays) shall be provided. These interposing relays will have dust proof covers. The dwell time of the output relay shall be continuously adjustable from 10 milliseconds to 5 seconds. Relays shall be rated for 125 VDC, 5A operation, with a minimum of two Form C contacts. The RTU response time must not be delayed by the dwell time of the relay.

4.7 Analog Inputs

1. Analog input points: eight required for this application
2. Analog values to be based on 0-5 VDC, differential type inputs.
3. Resolution: 12 bit
4. Common mode noise rejection: 80 dB.
5. Normal mode noise rejection: 60 dB.
6. Resistance: 10 Megaohm

4.8 Communication Interface

The system communication interface will allow the unit to be scanned by the MTU on a continuous basis. This hardware shall consist of a minimum of two asynchronous ports. The primary port shall consist of a Bell 202T modem to receive the transmit FSK signals at speeds between 1200 and 9600 bps. Light Emitting Diodes to indicate data receive, data transmit, request to send, clear to send, and error conditions shall be

included. Communication parameters such as baud rate, receiver gain, transmit output level, CTS delay and RTS delay shall be user-selectable through means of DIP switches or serial input from a lap top computer. The interface shall also be capable of transmitting and receiving data through an alternate medium such as licensed band frequency, wireless, or spread spectrum radio communication.

An RS-232 serial port shall also be included to serve as a user port for connection to a lap top PC used to configure the RTU or to run vendor-supplied diagnostic software. Additional port may include ports to establish communication with another RTU in a remote/sub-master configuration or to interface with intelligent electronic devices that could be installed in the future.

Each RTU will be equipped with a set of gas tubes that will protect the inputs against voltage spikes of up to 1000 VDC.

4.9 Enclosure. The RTU equipment shall be housed within a wall-mounted NEMA 4-rated cabinet, with panels or stretcher- leveled steel not less than No. 11 U.S. Gauge (5.0 pounds per square foot), with integral supported framework. The interior shall be finished with baked white enamel. The exterior shall be primed and finished with ANSI 61 non-glare gray lacquer. All surfaces shall be phosphatized prior to painting.

4.10 Battery Back-Up. Each RTU will have a battery back-up unit that will allow the RTU to operate for a minimum of 12 hours after the loss of primary power. The battery shall be a 24 volt sealed cell storage battery. The voltage and ampere rating shall be recommended by the manufacturer.

A battery charger shall be furnished to provide a floating charge to the battery. The charger shall have a set of contacts that close when the charger fails or is shut down. These contacts will be used for an indication of the charger status.

4.11 Communication Protocols

The RTU shall be capable of interfacing with both synchronous and asynchronous protocols. In addition to any vendor supplied proprietary protocols, the RTU shall be capable of communicating with external equipment using DNP 3.0 or the emerging UCA-compliant MRP protocol.

4.12 Environmental. Each RTU must be able to perform in a hostile environment that may include dust, moisture, electrical noise, and heat. The RTU will be able to function properly in temperatures ranging between -20 degrees Celsius and 60 degrees Celsius and humidities ranging between 5% and 95% without the aid of a fan.

4.13 Reliability. All RTU components should demonstrate a high degree of reliability in terms of mean time between failure (MTBF). The vendor shall provide all available data concerning potential defects and repair time for all components to be used in the unit.

4.14 Maintainability. The vendor shall provide all equipment necessary to ensure maintainability of the unit by reducing the mean time to repair (MTTR) on the unit. Such equipment should include a Valmet SmartSet test set which will be used as a diagnostic trouble-shooting tool and a complete set of spare parts to be located on-site

so that defective parts may be replaced immediately.

5.0 Supervisory Terminal Board (STB)

The installation shall include a supervisory terminal board which will serve as an interface between the RTU and the field equipment. All wiring for status, control, and analog points will pass through the STB, as control wiring from the station switchgear may be of a different variety than the wiring used within the SCADA RTU.

For this application, the STB will consist of three columns of 50 barrier-type terminal blocks, mounted on the back wall of a NEMA 12 cabinet. The cabinet shall be wall-mounted as shown on the Contract Drawings. The cabinet should be easily accessible from the front and leave enough space for work to be performed within. There should be enough terminal points available for all the station points as well as 20% spare points. All terminations points should be appropriately labeled so that wiring lists can be drawn up. A printed layout of the termination panel should be posted on the inside of the hinged door of the enclosure.

6.0 To Be Furnished By The Vendor

The Vendor shall furnish all the equipment and accessories specified herein, and all accessories and details not specifically mentioned or fully detailed but which is deemed necessary or which are reasonably required to make a complete and well integrated unit within the scope of this specification. The Vendor shall furnish, prior to the completion of the equipment, a complete set of drawings for approval by the Authority or Authority-designated representative. The drawings shall include detailed wiring diagrams, relay data, operations and maintenance manuals, mechanical drawings, outlines and sectional views, bills of material, and construction details including weights.

The vendor shall provide a qualified technical representative to the Authority to assist in the proper procedures for the correct installation, test, start up, trouble-shooting, maintenance, and check-out of the remote terminal units supplied under this contract. The technical representative must be fully qualified and experienced in supervisory systems and shall have the authority to represent and act for the supplier. The Vendor shall carry costs for this representation for five work days as directed by the Authority.

If the furnished equipment is not Valmet Automation equipment, the vendor shall provide verification that a Valmet SmartSet test set can be used for trouble-shooting purposes. The vendor will provide any auxiliary equipment that may be needed to interface any auxiliary equipment that may be needed to interface the RTU to the test set.

7.0 Information To Be Furnished With Bidders' Proposals

1. The Bidder shall submit with his bid a minimum of four (4) copies of his proposal.

2. The number of weeks required after receipt of order for submittal of drawings for approval.

3. The number of weeks required after the receipt of approved drawings for the shipment of equipment.

4. List of previously installed units of similar nature.

5. A verification that the system will work with a Valmet Sage Series VII system.

6. The bidder shall submit a detailed description and drawings of all equipment to be furnished by him and reliability data such as MTBF and MTTR.

8.0 Warranty of Equipment

All equipment furnished under this contract shall guaranteed for one year. The warranty period will begin at the time that the RTU is permanently integrated into the current SCADA system for revenue service operation.

During the guarantee period, any defective components or units, for which spare parts were provided to the Authority, shall be repaired or replaced within two weeks of receipt; defective components or units, for which spare parts were not provided, shall be repaired or replaced within 48 hours after receipt of such.

9.0 Final Acceptance And Maintenance

Prior to final acceptance, technical assistance shall be provided as required at no cost to the Authority. The Authority will make every attempt to resolve any problems encountered, during this time, with its own Engineers; but in the event that they can cannot resolve the problem, then technical assistance shall be required.

After the final acceptance and during the warranty period, the Authority will maintain the system. In the event that problems are encountered during this period of warranty and technical assistance is required, the manufacturer shall be reimbursed on a per diem basis for his technical assistance. In this vein, as part of the bid proposal, but not included in the lump sum bid price, all Bidders shall provide the total per diem costs for these services that shall remain the same during the life of the warranty period. It should be noted that if the defective components or units are the problem, technical representative costs are considered part of the warranty and no reimbursement will be provided.

SECTION 16450

GROUNDING

PART 1 – GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing and installing complete system neutral grounding, equipment grounding, and building structural grounding, in accordance with MBTA Standard Specifications Section 16450, except as modified herein.

B. The Contractor shall adhere closely to design guidelines depicted in the Association of American Railroads Signal Manual for recommended practices. References Volume 1, Section 2, Railway Signaling Systems and Volume 3, Section 11 entitled Circuit Protection.

1.02 SUBMITTALS

C. Manufacturer's Data: Shall be submitted for the following:

1. Ground Mats.
2. Ground Connectors.
3. Exothermic Welds.
4. 2" x ¼" ground bus system.

1.03 REFERENCES AND CODES

A. NEC – Table 250-122 – Grounding Conductors

B. NEC – Table 250-66 – Bonding Jumpers

PART 2 – PRODUCTS

2.01 MATERIALS AND EQUIPMENT, GENERAL:

B. All materials, equipment, and devices shall, as a minimum, meet the requirements of UL where UL standards are established for those items, and the requirements of NFPA 70. All equipment and materials provided shall be new, unless specified otherwise or indicated.

C. Grounding and Bonding Equipment: Shall conform to UL 467.

2.03 EXOTHERMIC WELDING

D. Application: The product shall be suitable, but not limited to, the following welding applications:

1. Cable to cable connections.

2. Cable to ground connections.

3. Cable to steel structure connections.

4. Cable to rebar connections.

5. Cable to pipe connections.

E. Product: Weld metal shall contain tin oxide. Starting material shall contain no phosphorous or other dangerous materials. Low emission type exothermic welding connections with battery start shall be used in all locations such as tunnels or other confined spaces.

2.04 BOLTED GROUNDING CONNECTIONS

B. Type:

1. NEMA 2-hole, copper compression type for all conductors #4/0 AWG and smaller.

2. NEMA 2-hole, long barrel, copper, double compression type for all conductors 250 Kcmil and larger.

C. Construction:

1. Lugs shall be tin plated to minimize corrosion.

2.06 GROUND RODS: Shall be copper sizes as shown on the Contract Drawings; UL approved. Ground rods shall be spaced at a minimum of 6 feet.

B. Size: Having diameter adequate to permit driving to full length of the rod, but not less than ¾ inch by 10 feet long.

2.07 FLEXIBLE GROUNDING JUMPERS

A. Braided copper, 1/8 inch by 1 inch, length as required, having suitable treatment for connection to zinc-coated steel.

PART 3 – EXECUTION

3.04 EQUIPMENT GROUNDING

A. At each station install one-quarter inch by two inch copper ground bus offset 2" off the wall, continuously around inside periphery and connect to grounding electrodes at intervals as indicated. Additionally, provide same type ground bus at periphery of electrical rooms and train control rooms.

3.05 BUILDING STRUCTURAL GROUNDING

A. Ground Bus: Provide copper ground bus loop sized as indicated, buried to a minimum depth of 2'-6" and in accordance with details as indicated.

3.08 FIELD QUALITY CONTROL

B. Testing Building Structural Grounding

1. General: After installation of the 2" x ¼" ground loop bus and ground electrodes, and prior to interconnection of other grounding systems perform ground resistance testing.

2. Test report: Provide the MBTA Power Systems, the times when the testing is to be done and report giving results of testing procedures, which shall also include temperature, humidity, and condition of soil at time of tests.

C. Resistance tests shall be made with approved industry standard testing equipment calibrated to industry standards.

3.09 HIGH VOLTAGE TRANSFORMER FENCING: Shall be grounded to the fence grounding ring. The fence grounding ring shall be bonded to the main station grounding. The fence grounding ring shall be installed 3'-0" outside the fence line.

A. Gate fence posts shall be bonded to fence grounding ring.

B. Barb wire strands shall be bonded to the fence.

C. All fence posts shall be bonded to the fence ground ring.

D. Every third line post shall be bonded to the fence ground ring.

PART 4 – MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Measurement and payment for Grounding Work of this Section, shall be complete in place with all costs included in the Contract Lump Sum Price for the work as indicated herein.

4.02 PAYMENT

A. Grounding as specified in this Section will be paid for at the Contract Lump Sum Price for Grounding Work.

4.03 PAYMENT ITEM

Item No.	Item Description	Unit
1625.000	GROUNDING SYSTEM	LS

END OF SECTION

SECTION 16460

TRANSFORMERS

PART 1 – GENERAL

1.01 DESCRIPTION

A. This Section specifies transformers in accordance with the MBTA Standard Specifications Section 16460 except as modified herein.

B. The Contractor shall adhere closely to design guidelines depicted in the Association of American Railroads Signal Manual for recommended practices. References Volume 1, Section 2, Railway Signaling Systems and Volume 3, Section 11, entitled Circuit Protection.

1.03 SUBMITTALS

E. Material and equipment requiring shop drawings or product data submittal shall include:

1. Transformers.

2. Outline drawing showing plan, elevation views and mounting dimensions including terminals, conduit entry, ground connections and weights.

3. Drawing of template data with nameplate data filled in.

PART 3 – EXECUTION

3.04 FACTORY TESTS

A. Shall be made in accordance with ANSI C57.12.91, as applicable.

B. Complete tests on the transformer(s) shall be made at the factory. Tests for transformers rated below 600 volts, shall include, but not be limited to, the following:

1. Ratio tests at the rated voltage connection and at all top connections.

2. Applied potential tests.

3. Induced potential tests.

4. Polarity and phase retention tests on the rated voltage connections.

Certified test results of previously built similar units will be accepted in lieu of actual tests.

PART 4 – MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Measurement and payment for Transformer Work of this Section, shall be complete in place, with all costs included in the Contract Lump Sum Price for the work as indicated herein.

4.02 PAYMENT

A. Transformers as specified in this Section will be paid for at the Contract Lump Sum Price for Transformer Work.

4.03 PAYMENT ITEM

Item No.	Item Description	Unit
1620.025	TRANSFORMERS	EA

END OF SECTION

SECTION 16471

DISTRIBUTION AND BRANCH CIRCUIT PANELBOARDS

PART 1 – GENERAL

1.01 DESCRIPTION

A. This Section specifies distribution and branch circuit panelboards in accordance with MBTA Standard Specifications Section 16471, except as modified herein.

1.02 QUALITY CONTROL

D. Panelboards used at service entrance shall be suitable for service entrance applications. Refer to contract drawings.

1.03 SUBMITTALS

E. Material and equipment requiring shop drawings or product data submittal shall include:

1. Panelboards.

2. Circuit Breakers.

PART 2 – PRODUCTS

2.02 CIRCUIT BREAKERS

I. Circuit breakers shall be industrial type.

2.04 PANELBOARDS

Q. Panelboards shall be furnished with an insulated neutral copper bus and a suitable copper grounding bus.

2.08 LIGHTING PANELBOARDS

A. Lighting panelboards shall be 480/277 Volt, three phase, four wire, and shall have single pole, 277 Volt, bolt-in type molded case circuit breakers in the quantities and sizes indicated on the Contract Drawings.

B. Panelboards shall have hinged trim covers.

C. Panelboards shall be Door In Door type.

2.09 MISCELLANEOUS POWER AND LIGHTING PANELBOARDS

A. Miscellaneous power and lighting panelboards shall be 208/120 Volt, three phase, four wire, or 480/277 Volt, 3 phase, 4 wire and shall have bolt-in molded case circuit breakers in the quantities and sizes indicated.

B. Panelboards shall have hinged trim covers.
C. Panelboards shall be Door In Door Type.

PART 4 – MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Measurement and payment will be made for Panelboard Work of this Section, complete in place, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

4.02 PAYMENT

A. Panelboards as specified in this Section will be paid for at the Contract Lump Sum Price for Panelboard Work.

4.03 PAYMENT ITEM

Item No.	Item Description	Unit
1633.090	Distribution and Branch Circuit Panelboards	LS

END OF SECTION

SECTION 16500

LIGHTING

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the removal and relocation of existing street lighting, furnishing and installation of new Station and street lighting systems, lighting systems for Unit Substation B2 and Vent Shaft B3, complete and operable, as indicated, including fixtures; fixture mounting hardware including brackets, canopies, hangers, and poles; lamps; auxiliary lighting equipment; and lighting control equipment as indicated on the Contract Drawings and in accordance with the Standard MBTA Specifications Construction Section 16500, except as modified herein.

C. The work shall include but not limited to the following:

1. Complete shop fabrication.
2. Delivery to the job site.
3. Installation at designated locations and controls as noted.
4. Lamping and lamps.
5. Focusing of all adjustable fixtures.
6. Cleaning and protection.
7. Furnish and install a lighting fixture of the type indicated at each location shown on the construction drawings.
8. All materials, accessories and any other equipment necessary for the complete and proper installation of all lighting fixtures included in this contract.

D. This Section specifies the removal of existing Station lighting fixtures, cable and raceways and furnishing and installing of new luminaries, raceways and cable for new lighting systems for the entire station as indicated herein.

E. Supply temporary lighting for the duration of the construction to the areas impacted by the station modifications, to maintain a level of illumination equal to or more than the existing lighting system. As part of this effort conduct a field survey of the existing lighting levels at the existing platform and surface areas. Any additional lighting needed for construction is the responsibility of the Contractor.

F. Protect in-place any systems that will not be impacted by station modifications.

G. Demolish existing lighting in the station as indicated and replace with new sub-panel feed circuits, wiring, raceways, luminaries and controls.

H. Base Contract includes new Station lighting as well as surface/street lighting located around the North Head House Entrance. The Base Contract shall include new lighted bollards at the

pedestrian cross-walks at the North Head House, one (1) new pole and relocation of existing poles based on new curb lines.

I. The scope includes the installation of new street lighting as indicated on the Contract Plans. All wiring and lighting controls shall be by the City of Boston Lighting Dept. See Electrical Site Lighting Plans for location of luminaries.

1.02 QUALITY CONTROL

A. Fixtures and auxiliary equipment shall be listed, labeled or certified by UL. Fixtures shall be manufactured in strict accordance with the contract drawings and specifications.

B. Materials and installation shall be in accordance with the latest revision of the National Electric Code and any applicable Federal, State and Local Codes and regulations.

C. Specifications and scale drawings are intended to convey the salient features, function and characteristics of the fixtures only and do not illustrate or provide every detail for the work. Minor details not usually indicated on the drawings nor specified herein, but are necessary for the proper execution and completion of the fixtures shall be included.

D. Omissions – The Authority shall not be responsible for omission or absence of any detail, construction feature, etc. which may be required in the fabrication of the fixtures. The responsibility of accurately fabricating the fixtures rests completely with the Contractor.

E. Replace lamps which fail within 90 days after final acceptance, at no cost to the owner.

F. Installation Tolerances. Deviation from location, alignment and mounting height: 1/2 inch non-cumulative in any unit or continuous run of fixtures.

1.03 SUBMITTALS

A. Submit shop drawings, catalog cuts, descriptive information and photometric data for lighting fixtures, lamps, auxiliary lighting equipment, lighting control equipment, and mounting hardware. Shop drawings shall be received no later than sixty days after award of Contract.

C. The Contractor shall coordinate all lighting fixture drawings with the drawings and details of the Architectural, Structural, Electrical and Mechanical and any other trades to assure an efficient installation.

1.05 SAMPLES

A. If specified, before production is commenced, submit a sample fixture of each style, mounting and lamp arrangement specified. Reports indicating that required tests specified have been successfully completed shall accompany each pre-production sample at the time it is submitted. The sample, if approved, will be retained until completion of the work to confirm quality conformance to the prescribed requirements herein. Provide the sample for operation at 120 volts

with six foot cord and plug. Sample fixtures shall be shipped, prepaid by the Contractor, to the Engineer or as otherwise indicated in the Contract Documents.

C. Sufficient time shall be allowed for thorough examination of the samples by the Engineer.

D. Samples are not returnable and are not included in the listed quantities for the project.

E. Samples must be actual working unit of materials to be supplied.

1.06 DELIVERY, STORAGE AND HANDLING

A. Deliver materials to the site ready for use in the manufacturer's original container, bearing labels and tag numbers. Delivered material shall be identical to reviewed submittals.

B. Store materials under cover in a clean dry location, off the ground. Remove materials which are damaged or otherwise not suitable for installation from the jobsite and replace accordingly.

1.07 WARRANTY

A. The electrical Contractor and Manufacturer shall guarantee all lighting fixtures and major components, except lamps, for a period of one (1) year after acceptance of the work and final payment is made. The guarantee shall be in an acceptable form to the Engineer and shall be signed and notarized by a person or persons authorized to execute such a document on behalf of the company.

1.08 PRE-QUALAFICATIONS

A. The luminaire manufacturer must be prequalified as an approved manufacturer/fabricator. The prequalifying applicant must submit documentation that indicates the manufacturer has been in business for the past five years as a fabricator, assembler and finisher for luminaries of the magnitude and quantity to those specified.

1.09 RELATED SECTIONS

A. Section02455 Metal Bollards

PART 2 - PRODUCTS

2.01 LIGHTING FIXTURES

A. General Requirements

B. Materials.

3. Concrete for base foundations shall be Section 03310, Portland Cement Concrete; Section

03200, Concrete Reinforcement.

D. Electrical Components

2. Ballasts

k. Magnetic: Where called for in the Lighting Fixture Schedule provide magnetic ballast for fluorescent light fixtures. Contractor is responsible for coordination of ballast with specified lamps. Magnetic ballast shall be acceptable and listed by UL.

2.02 FIXTURE MOUNTING HARDWARE

2.03 LAMPS

A. General Requirements. Provide each lighting fixture with the number type, and wattage of lamps required by the Contract Drawings. Provide lamps of standard manufacture, readily available, and of the highest efficiency as recommended by Mass. Energy Code and life consistent with other requirements of the illumination system.

2.04 AUXILIARY LIGHTING EQUIPMENT

B. Delete.

C. Delete.

PART 3 - EXECUTION

3.08 TESTING AND COMMISSIONING

A. Energize all luminaries and verify operation.

B. With temporary lighting turned off and final lighting on, conduct an area survey of illumination and note on a set of plans lumen levels. Submit to Engineer for approval.

PART 4 - MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Station lighting fixtures will be measured as a unit for each type, including removal of existing fixtures, temporary lighting as needed, new lamps, ballasts, lampholders, globes and lenses, hardware, and other accessories and incidentals, and including 10 percent additional lamps,

ballasts, lampholders, globes and lenses, hardware, and other accessories and incidentals, complete in place.

B. Street Lighting fixtures will be measured under item 1640.022 including lamps, ballasts, lampholders, globes and lenses, hardware, poles, and other accessories and incidentals, and including 10 percent additional lamps, ballasts, lampholders, globes and lenses, hardware, poles and other accessories and incidentals, complete in place.

C. Lighted Metal Bollards shall be measured under Section 02455. No separate payment item shall be included in this Section.

D. Relocated Street Lighting fixtures will be measured as a unit for each type, including removal of existing pole, storage and replacement on its relocated base.

E. No separate measurement nor payment will be made for lighting work required for the tunnel emergency ventilation system for Unit Substation B2 and Ventilation Shaft B3 but all cost shall be included in pay item TUNNEL VENTILATION SYSTEM on a lump sum basis furnished and installed complete in place as shown on the Contract Drawings and as specified herein.

4.02 PAYMENT

A. New Station Lighting shall be paid for at Contract Lump Sum Price for Station Lighting Fixtures.

B. Lighted Metal Bollards shall be paid for in Section 02455 – Metal Bollards.

C. Relocated Street Lighting shall be paid for at the Contract Unit Price Each for Relocated Single Street Light.

Item No.	Description	Unit
1640.010	Station Lighting Fixtures	LS
1640.022	Street Light, 2 luminaries with Base	EA
1640.024	Relocated Single Street Light	EA
1586.040	Tunnel Ventilation System	LS

END OF SECTION

SECTION 16630

EMERGENCY GENERATOR

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the furnishing, installation, connecting, testing, and placing in operation the 235 KW Emergency Generator. The system shall be complete and operational with Transfer Switch per Section 16640. This Section supercedes MBTA Section 16620, Emergency Power Systems.

B. Provide factory test, startup by a supplier authorized by the manufacturer, and on-site testing of the system.

C. The generator set manufacturer shall warrant all equipment provided under this section, whether or not is manufactured by the generator set manufacturer, so that there is one source for warranty and product service. Technicians specifically trained and certified by the manufacturer to support the product and employed by the generator set supplier shall service the generator sets.

1.02 CODES AND STANDARDS

A. The generator set and its installation and on-site testing shall conform to the requirements of the following codes and standards:

1. NEC - National Electric Code
2. 527 CMR 12.00 Massachusetts Electric code
3. IEC8528 part 4. Control Systems for Generator Sets
4. IEEE446 – Recommended Practice for Emergency and Standby Power Systems for Commercial and Industrial Applications
5. NEMA ICS10 – AC Generator sets.
6. NFPA70 – National Electrical Code. Equipment shall be suitable for use in systems in compliance to Article 700, 701, and 702.
7. NFPA110 – Emergency and Standby Power Systems. The generator set shall meet all requirements for Level 1 systems. Level 1prototype tests required by this standard shall have been performed on a complete and functional unit, component level type tests will not substitute for this requirement.
8. ASTM A53. American Society for Testing and Materials (ASTM) Pipe, steel, black and hot-Dripped, Zinc-Coated Welded and Seamless.
9. ASTM A181. American Society for Testing and Materials (ASTM) Forging, Carbon Steel, for General Purpose Piping.
10. UL489. Circuit Breakers, Molded Case, and Circuit Breakers Enclosed

11. UL2200. The Gen-set shall be listed to UL2200 or submit to an independent third party certification process to verify compliance as installed.

12. The emergency generator shall be installed in accordance with FM Global Data Sheet 5-23 and the gas piping in accordance with Data Sheet 7-54 both available upon request from FM Global, a Factory Mutual Insurance Company, 500 River Ridge Drive, P.O Box 9102, Norwood, MA 02062. T: (781) 440-8000 F: 781-440-8718.

B. The generator set manufacturer shall be certified to ISO 9001 International Quality Standard and shall have third party certification verifying quality assurance in design/development, production, installation, and service, in accordance with ISO 9001.

1.03 GENERAL REQUIREMENTS

A. General Requirements include those as specified herein. Materials not normally furnished by the manufacture with this equipment are specified in:

1. Section 16050 – Basic Materials and Methods for Electrical Work

2. Section 16120 – Wires and Cables

3. Section 16450 – Grounding

4. Section 16640 – Automatic Transfer Switch

1.04 SUBMITTALS

A. Manufacturer's product literature and performance data, sufficient to verify compliance to specification requirements.

B. Manufacturer's certification of prototype testing.

C. Manufacturers published warranty documents.

D. Shop drawings showing plan and elevation views with certified overall dimensions, as well as wiring interconnection details.

E. Interconnection wiring diagrams showing all external connections required; with field wiring terminals marked in a consistent point-to-point manner.

F. Manufacturer's installation instructions.

1.05 FACTORY TESTING

A. The generator set supplier shall perform a complete operational test on the generator set prior to shipping from the factory. A certified test report shall be provided. Equipment supplied shall be fully tested at the factory for function and performance.

B. Factory testing may be witnessed by the owner and consulting engineer. Costs for travel expenses will be the responsibility of the owner and consulting engineer. Supplier is responsible to provide two weeks notice for testing.

C. Generator set factory tests on the equipment shall be performed at rated load and rated power factor. Generator sets that have not been factory tested at rated power factor will not be acceptable. Tests shall include: run at full load, maximum power, voltage regulation, transient and steady-state governing, single step load pickup, and function of safety shutdowns.

1.06 WARRANTY

A. The generator set and associated equipment shall be warranted for a period of not less than 5 years from the date of commissioning against defects in materials and workmanship.

B. The warranty shall be comprehensive. No deductibles shall be allowed for travel time, service hours, repair parts cost, etc.

1.07 TRAINING

A. The equipment supplier shall provide training for the facility operating personnel covering operation and maintenance of the equipment provided. The training program shall be not less than 6 hours in duration and the class size shall be limited to 5 persons. Training date shall be coordinated with the facility owner.

1.08 SERVICE AND SUPPORT

A. The manufacturer of the generator set shall maintain service parts inventory at a central location which is accessible to the service location 24 hours per day, 365 days per year.

B. The generator set shall be serviced by a local service organization that is trained and factory certified in generator set service. The supplier shall maintain an inventory of critical replacement parts at the local service organization, and in service vehicles. The service organization shall be on call 24 hours per day, 365 days per year.

PART 2 – PRODUCTS

2.01 GENERATOR SET

A. Ratings

1. The 235 KW generator set shall operate at 1800 rpm and at a voltage of 277/480Volts AC, Three phase, Four-wire, 60 hertz.

2. The generator set shall be rated as indicated at 0.8 PF, 100% rating, based on site conditions of: Elevation – Sea Level, ambient temperatures - 55 to 80 degrees F.

3. The generator set rating shall be based on emergency/standby service.

B. Performance

1. Voltage regulation shall be plus or minus 1.0 percent for any constant load between no load and rated load for both parallel and non-parallel applications. Random voltage variation with any steady load from no load to full load shall not exceed plus or minus 0.5 percent.

2. Frequency regulation shall be isochronous from steady state no load to steady state rated load. Random frequency variation with any steady load from no load to full load shall not exceed plus or minus 0.25%.

3. The natural gas engine-generator set shall be capable of single step load pick up of 100% nameplate kW and power factor, less applicable derating factors, with the engine-generator set at operating temperature.

4. Motor starting capability shall be a minimum of kVA as indicated on the Contract Drawings. The generator set shall be capable of sustaining a minimum of 90% of rated no load voltage with the specified kVA load at near zero power factor applied to the generator set.

5. The alternator shall produce a clean AC voltage waveform, with not more than 5% total harmonic distortion at full linear load, when measured from line to neutral, and with not more than 3% in any single harmonic. Telephone influence factor shall be less than 40.

C. Construction

1. The engine-generator set shall be mounted on a heavy-duty steel base to maintain alignment between components. The base shall incorporate a battery tray with hold-down clamps within the rails

D. Connections

1. The generator set load connections shall be composed of silver or tin plated copper bus bars, drilled to accept mechanical or compression terminations of the number and type as shown on the drawings. Sufficient lug space shall be provided for use with cables of the number and size as shown on the drawings.

2. Power connections to auxiliary devices shall be made at the devices, with required protection located at a wall-mounted common distribution panel.

3. Generator set control interfaces to other system components shall be made on a common, permanently labeled terminal block assembly.

2.02 ENGINE AND ENGINE EQUIPMENT

A. The engine shall be natural gas fueled, radiator and fan cooled. The horsepower rating of the engine at its minimum tolerance level shall be sufficient to drive the alternator and all connected accessories.

B. The engine shall be designed to operate on 4" inches of water column dynamic pressure natural gas without a booster pump.

C. Complete engine fuel system, including all pressure regulators, strainers, and control valves. The fuel system shall be plumbed to the generator set skid for ease of site connections to the generator set.

D. An electronic governor system shall provide automatic isochronous frequency regulation.

E. Skid-mounted radiator and cooling system rated for full load operation in 104 degrees F (40 degrees C) ambient as measured at the generator air inlet, based on 0.5 in H_2O external static head. Radiator shall be sized based on a core temperature which is 20F higher than the rated operation temperature, or prototype tested to verify cooling performance of the engine/radiator/fan operation in a controlled

environment. Radiator shall be provided with a duct adapter flange. The equipment manufacturer shall fill the cooling system with a propylene glycol/water mixture suitable to protect against freezing (location - Boston Massachusetts). Rotating parts shall be guarded against accidental contact.

F. Electric starter(s) capable of three complete cranking cycles without overheating.

G. Positive displacement, mechanical, full pressure, lubrication oil pump.

H. Full flow lubrication oil filters with replaceable spin-on canister elements and dipstick oil level indicator.

I. Replaceable dry element air cleaner with restriction indicator.

J. Flexible fuel lines.

K. Engine mounted battery charging alternator, 40-ampere minimum, and solid-state voltage regulator.

L. Coolant heater

1. Engine mounted, thermostatically controlled, coolant heater(s) for each engine. Heater voltage shall be as shown on the project drawings. The coolant heater shall be UL499 listed and labeled.

2. The coolant heater shall be installed on the engine with silicone hose connections. Steel tubing shall be used for connections into the engine coolant system wherever the length of pipe run exceeds 12 inches. The coolant heater installation shall be specifically designed to provide proper venting of the system. The coolant heaters shall be installed using quick disconnect couplers to isolate the heater for replacement of the heater element. The quick disconnect/automatic sealing couplers shall allow the heater element to be replaced without draining the engine cooling system or significant coolant loss.

3. The coolant heater shall be provided with a 24VDC thermostat, installed at the engine thermostat housing. An AC power connection box shall be provided for a single AC power connection to the coolant heater system.

4. The coolant heater(s) shall be sized as recommended by the engine manufacturer to warm the engine to a minimum of 100F (40C) in a 40F ambient, in compliance with NFPA110 requirements, or the temperature required for starting and load pickup requirements of this specification.

M. Provide vibration isolators, spring/pad type, quantity as recommended by the generator set manufacturer. Isolators shall include seismic restraints designed for the city of Boston, Massachusetts. A Commonwealth of Massachusetts Registered Professional Engineer shall design seismic restraints. Stamped calculations shall be submitted.

N. Starting and Control Batteries shall be, 24 volt DC, sized as recommended by the engine manufacturer, complete with battery cables and connectors.

O. Provide exhaust silencer(s) and flexible connection for each engine of size and type as recommended by the generator set manufacturer and approved by the engine manufacturer. The mufflers shall be "Critical Grade". Exhaust system shall be installed according to the engine manufacturer's recommendations and applicable codes and standards.

P. A UL listed/CSA certified 10 amp voltage regulated battery charger shall be provided for the engine-generator set. The charger may be located in an automatic transfer switch, or may be wall mounted, at the discretion of the installer. Input AC voltage and DC output voltage shall be as required. Chargers shall be equipped with float, taper and equalize charge settings. Operational monitors shall provide visual output along with individual form C contacts rated at 4 amps, 120 VAC, 30VDC for remote indication of:

- Loss of AC power - red light
- Low battery voltage - red light
- High battery voltage - red light
- Power ON - green light (no relay contact)

Charger shall include an Analog DC voltmeter and ammeter, 12 hour equalize charge timer, and AC and DC fuses

2.03 AC GENERATOR

A. The AC generator shall be; synchronous, four pole, 2/3 pitch, revolving field, drip-proof construction, single pre-lubricated sealed bearing, air cooled by a direct drive centrifugal blower fan, and directly connected to the engine with flexible drive disc. All insulation system components shall meet NEMA MG1 temperature limits for Class H insulation system. Actual temperature rise measured by resistance method at full load shall not exceed 125 degrees Centigrade.

B. The generator shall be capable of delivering rated output (kVA) at rated frequency and power factor, at any voltage not more than 5 percent above or below rated voltage.

C. A permanent magnet generator (PMG) shall be included to provide a reliable source of excitation power for optimum motor starting and short circuit performance. The PMG and controls shall be capable of sustaining and regulating current supplied to a single phase or three phase fault at approximately 300% of rated current for not more than 10 seconds.

D. The sub-transient reactance of the alternator shall not exceed 12 percent, based on the standby rating of the generator set.

2.04 ENGINE-GENERATOR SET CONTROL

A. A NEMA 1 enclosed control panel shall be mounted on the generator set with vibration isolators. The control shall be vibration isolated and prototype tested to verify the durability of all components under the vibration conditions encountered. The generator set mounted control shall include the following features and functions:

B. Three position control switch labeled RUN/OFF/AUTO. In the RUN position the generator set shall automatically start, and accelerate to rated speed and voltage. In the OFF position the generator set shall immediately stop, bypassing all time delays. In the AUTO position the generator set shall be ready to accept a signal from a remote device to start and accelerate to rated speed and voltage.

C. EMERGENCY STOP switch: Switch shall be Red "Mushroom-Head" pushbutton depressing the Emergency Stop switch shall cause the generator to immediately shutdown and be locked out from Automatic Restarting.

D. RESET switch. The RESET switch shall be used to clear a fault and allow restarting the generator set after it has shut down for any fault condition.

E. PANEL LAMP switch. Depressing the panel lamp switch shall cause the entire panel to be lighted with DC control power.

F. Generator Set AC Output Metering: The generator set shall be provided with a metering set with the following features and functions:

1. Analog AC Voltmeter, dual range, 90 degree scale, 2% accuracy; Analog AC Ammeter, dual range, 90 degree scale, 2% accuracy; Analog Frequency/RPM meter, 45-65 Hz, 1350-1950 RPM, 90 degree scale, +/- 0.6 Hz accuracy.

2. Seven position phase selector switch with OFF position to allow meter display of current and voltage in each generator phase. When supplied with reconnectable generators, the meter panel shall be reconnectable for the voltage specified.

G. Generator Set Alarm and Status Display: The generator set shall be provided with alarm and status indicating lamps to indicate non-automatic generator status, and existing alarm and shutdown conditions. The lamp condition shall be clearly apparent under bright room lighting conditions. The generator set control shall be NFPA 110 compliant and indicate the existence of the following alarm and shutdown conditions on the display panel:

- low oil pressure pre-alarm (alarm)
- low oil pressure (alarm)
- low oil pressure (shutdown)
- low coolant temperature (alarm)
- high engine temperature pre-alarm (alarm)
- high coolant temperature (alarm)
- high coolant temperature (shutdown)
- low coolant level (shutdown)
- overcrank (alarm & shutdown)
- overspeed (alarm & shutdown)
- low fuel pressure (alarm)
- control switch not in Auto. position (Alarm)
- high battery voltage (alarm)
- low battery voltage (alarm)
- battery charge AC failure (alarm)
- lamp test (alarm)
- ground fault (alarm)(optional--when required by code or specified)

In addition, provisions shall be made for indication of two customer-specified alarm or shutdown conditions. The non-automatic indicating lamp shall be red, and shall flash to indicate that the generator set is not able to automatically respond to a command to start from a remote location.

H. Engine Status Monitoring: The following devices shall be provided on the generator set control:

- engine speed
- engine oil pressure gauge
- engine coolant temperature gauge
- engine operation hour gauge

- battery voltage (DC volts)
- engine oil temperature

I. Engine Control Functions: The control system provided shall include a cycle cranking system, which shall be for 3 cranking periods of 15 seconds each, with 15 second rest period between cranking periods. Fail to start shall be indicated by operation of the overcrank alarm indication lamp. The control system shall also include an engine governor control, which functions to provide steady state frequency regulation as noted elsewhere in this specification.

J. Alternator Control Functions:

1. The generator set shall include an automatic voltage regulation system which is matched and prototype tested with the governing system provided. It shall be immune from mis-operation due to load-induced voltage waveform distortion and provide a pulse width modulated output to the alternator exciter. The system shall include a torque-matching characteristic, which shall reduce output voltage in proportion to frequency below a threshold of [58-59] HZ.

2. Voltage adjusting rheostat, locking screwdriver type, to adjust voltage +/- 5% from rated value;

K. Control Interfaces for Remote Monitoring. Provide the following features in the control system:

1. Form "C" dry common alarm contact set rated 2A @ 30VDC to indicate existence of any alarm or shutdown condition on the generator set.

2. One set of contacts rated 2A @ 30VDC to indicate generator set is ready to load. The contacts shall operate when voltage and frequency are greater than 90% of rated condition.

L. The generator set shall be provided with a mounted main line circuit breaker, sized to carry the rated output current of the generator set on a continuous basis. The breaker shall incorporate a thermal-magnetic trip for overcurrent.

M. Provide and install a LED type remote alarm annunciator with horn, located as shown on the drawings. The remote annunciator shall provide all the audible and visual alarms called for by NFPA Standard 110 for level 1 systems; and in addition shall provide indications for high battery voltage, low battery voltage, loss of normal power to the charger. Spare lamps shall be provided to allow future addition of other alarm and status functions to the annunciator. Provisions for labeling of the annunciator in a fashion consistent with the specified functions shall be provided. Alarm silence and lamp test switch(es) shall be provided. LED lamps shall be replaceable, and indicating lamp color shall be capable of changes needed for specific application requirements. Alarm horn shall be switchable for all annunciation points. Alarm horn (when switched on) shall sound for first fault, and all subsequent faults, regardless of whether first fault has been cleared, in compliance with NFPA110 3-5.6.2.

N. Provide 120 VAC relay to open air intake dampers and radiator discharge dampers.

2.05 ACCEPTABLE MANUFACTUERS

A. Caterpillar

B. Cummins

C. Kohler

PART 3 – OPERATION

3.01 INSTALLATION

A. Equipment shall be installed by the contractor in accordance with final submittals and contract documents. Installation shall comply with applicable state and local codes as required by the authority having jurisdiction. Install equipment in accordance with manufacturer's instructions and instructions included in the listing or labeling of UL listed products.

B. Installation of equipment shall include furnishing and installing all interconnecting wiring between all major equipment provided for the on-site power system. The contractor shall also perform interconnecting wiring between equipment sections (when required), under the supervision of the equipment supplier.

C. Equipment shall be installed on concrete housekeeping pads. Equipment shall be permanently fastened to the pad in accordance with manufacturer's instructions and seismic requirements of the site.

D. Equipment shall be initially started and operated by representatives of the manufacturer.

E. All equipment shall be physically inspected for damage. Scratches and other installation damage shall be repaired prior to final system testing. Equipment shall be thoroughly cleaned to remove all dirt and construction debris prior to final testing of the system.

3.02 SEQUENCE OF OPERATION

A. Generator set shall start on receipt of a start signal from remote equipment.

B. The generator set control shall initiate the starting sequence for the generator set. The starting sequence shall include the following functions:

1. The engine shall accelerate to rated speed and the alternator to rated voltage. Excitation shall be disabled until the engine has exceeded programmed idle speed, and regulated to prevent over voltage conditions and oscillation as the engine accelerates and the alternator builds to rated voltage.

C. When all start signals have been removed from the generator set, the generator set control shall switch off the excitation system and shall shut down.

1. Any start signal received after the time stop sequence has begun shall immediately terminate the stopping sequence and return the generator set to isochronous operation.

D. Sequence of Operation shall comply with NFPA 110.

3.03 ON-SITE ACCEPTANCE TEST

A. The complete installation shall be tested for compliance with the specification following completion of all site work. Testing shall be conducted by representatives of the manufacturer, with required fuel supplied by Contractor. The Engineer shall be notified in advance and shall have the option to witness the tests.

B. Installation acceptance tests to be conducted on-site shall include a "cold start" test, a two hour full load test, and a one step rated load pickup test in accordance with NFPA 110. Provide a resistive load bank

and make temporary connections for full load test, for a minimum of two hours or as required by MBTA..

C. Perform a power failure test on the entire installed system. This test shall be conducted by opening the power supply from the utility service, and observing proper operation of the system for at least 2 hours. Coordinate timing and obtain approval for start of test with site personnel.

PART 4 – MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Measurement and payment will be made for Emergency Generator Work of this section, complete in place, with all costs included in the Contract Lump Sum Price for the work as indicated herein.

4.02 PAYMENT

B. Emergency Generator Work as specified in this Section will be paid for at the Contract lump sum price for Emergency Generator Work.

4.03 PAYMENT ITEM

Item No.	Item Description	Unit
1630.021	EMERGENCY GENERATOR SYSTEM	LS

END OF SECTION

SECTION 16640

LOW VOLTAGE AUTOMATIC TRANSFER SWITCHES

PART 1 – GENERAL

1.01 DESCRIPTION

A. This Section specifies the furnishing, installing, connecting, testing and placing into operation low voltage automatic transfer switches having the ratings, features/accessories and enclosures as specified herein. The system shall be complete and operational with Emergency Generator per Section 16630. Sizing shall be as indicated.

B. Provide factory test, on-site testing of the system.

1.02 CODES AND STRANDARDS

A. The automatic transfer switches and all components shall be designed, manufactured and tested in accordance with the latest applicable standards of UL and NEMA as follows:

1. UL 1008 – Transfer Switches
2. UL 991
3. NFPA 70 – National Electrical Code
4. NFPA 110 – Emergency and Standby Power Systems
5. NEMA ICS 10 – AC Transfer Switch Equipment
6. IEEE 446 – Recommended Practice for Emergency and Standby Power Systems

B. The transfer switch manufacturer shall be certified to ISO 9001 International Quality Standard and shall have third party certification verifying quality assurance in design/development, production, installation, and service, in accordance with ISO 9001.

1.03 GENERAL REQUIREMENTS

A. General Requirements include those as specified herein. Materials not normally furnished by the manufacture with this equipment are specified in:

1. Section 16050 – Basic Materials and Methods for Electrical Work
2. Section 16450 – Grounding
3. Section 16630 – Emergency Generator

1.04 SUBMITTALS

A. The following information shall be submitted to the Engineer:

1. Master drawing index
2. Front view and plan view of the assembly
3. Schematic diagram
4. Nameplate schedule
5. Component list
6. Conduit space locations within the assembly.
7. Assembly ratings including:
    a. Short-circuit rating
    b. Voltage
    c. Continuous current rating.
8. Major component ratings including:
    a. Voltage
    b. Continuous current rating
    c. Interrupting ratings
9. Cable terminal sizes
10. Product Data Sheets.

B. The following information shall be submitted for record purposes:

1. Final as-built drawings and information for items listed in Article 1.04
2. Wiring diagrams
3. Certified production test reports
4. Installation information
5. Seismic certification
6. Operation and Maintenance Manual

C. Manufacturer's published Warranty documents.

D. Manufacturer's installation instructions.

1.05 QUALIFICATIONS

A. The manufacturer of the assembly shall be the manufacturer of major components and control modules installed within the assembly.

1. The manufacturer of this equipment shall have produced similar electrical equipment for a minimum period of ten (10) years. When requested by the engineer, an acceptable list of installations with similar equipment shall be provided demonstrating compliance with this requirement.

1.06 REGULATORY REQUIREMENTS

A. Provide a certificate of compliance with UL 1008 for the transfer switches furnished under this section.

1.07 DELIVERY, STORAGE AND HANDLING

A. Equipment shall be handled and stored in accordance with manufacturer's instructions. One (1) copy of these instructions shall be included with the equipment at time of shipment.

B. Equipment operation and maintenance manuals shall be provided with each assembly shipped, and shall include instruction leaflets and instruction bulletins for the complete assembly and each major component.

1.08 TRAINING

A. The equipment supplier shall provide training for the facility operating personnel covering operation of the assembly, circuit breakers, within the assembly and major components. The training program should be not less than one 8-hour day in duration and the class size shall be limited to five (5) persons. Training date shall be coordinated with the MBTA.

1.09 SERVICE AND SUPPORT

A. The manufacturer of the Automatic Transfer Switch shall maintain service parts inventory at a central location which is accessible to the service location 24 hours per day, 365 days per year.

B. The Automatic Transfer Switch shall be serviced by a local service organization that is trained and factory certified in ATS service. The supplier shall maintain an inventory of critical replacement parts at the local service organization and in service vehicle. The service organization shall be on call 24 hours per day, 365 days per year.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Cummins Onan

B. Cutler-Hammer

C. ASCO

D. Russelelectric

E. Or approved equivalent

2.02 RATINGS

A. The transfer switch shall have equal "withstand", "closing" and "interrupting" ratings as indicated.

B. Main contacts shall be rated for the operation voltage as installed.

C. The transfer switch shall be rated to carry 100% equipment rated continuously in the enclosure supplied, in ambient temperatures of –40 to +60 degree C, relative humidity up to 95% (non-condensing).

D. Transfer switch equipment shall have withstand and closing rating (WCR) in RMS symmetrical amperes or 100 KAIC and make same as MSB Rating shown on the drawings. The transfer switch and its upstream protection shall be coordinated. The transfer switch shall be third party listed and labels for use with the specified protective device(s) installed in the application.

2.03 CONSTRUCTION

A. The switching panel shall consist of completely enclosed contact assemblies and a separate control logic panel. Control power for all transfer operations shall be derived from the line side of the source to which the load is being transferred.

B. The transfer switch shall be mechanically interlocked to prevent cross connection of sources when operated either automatically, or manually.

C. Transfer switches shall be capable of being operated manually under full rated load conditions. Manual operation shall be accomplished by a permanently attached manual operator, or by integrally mounted pushbuttons. Removable manual operating handles, and handles that may move in the event of an electrical operation during the manual operation, are not acceptable. Manual operators requiring source or load disconnection prior to manual operation are not acceptable.

D. On transfer switches requiring a fourth pole for switching the neutral, the neutral shall be fully rated with equal withstand, closing and interrupting ratings to the power poles. Switched neutral poles which are add-on or overlap, or that are not capable of breaking full rated load current are not acceptable.

E. The transfer switch shall have a multi-tap voltage selection plug for ease of voltage adjustment in the field.

F. Enclosure shall be UL listed and NEMA 1 rated. The enclosure shall provide NEC wire bend space when both sources and the load are all connected from either the top or bottom of the transfer switch. The cabinet door shall be key-locking.

2.04 WIRING/TERMINATIONS

A. The main transfer switch terminals shall be suitable for the termination of conductors shown on the plans and the full output rating of the generator set. Field connections shall be made on a terminal block that is clearly and permanently labeled.

2.05 OPERATIONS TRANSFER SWITCH CONTROL

A. Solid-state under voltage sensors shall simultaneously monitor both sources. Pick-up and drop-out settings shall be adjustable. Voltage sensors shall have field calibration of actual supply voltage to nominal system voltage.

B. Automatic controls shall signal the engine-generator set to start upon signal from normal source sensor. Solid-state time delay start, adjustable from 0 to 15 seconds (factory set at 2 seconds) shall avoid nuisance start-ups. Battery voltage starting contacts shall be silver, dry type contacts factory wired to a field wiring terminal block.

C. The switch shall transfer when the emergency source reaches the set point. Provide a solid-state time delay on transfer, adjustable from 2 to 120 seconds, factory set at 3 seconds.

D. The switch shall retransfer the load to the normal source after a time delay retransfer, adjustable from 6 seconds to 30 minutes, factory set at 5 minutes. Retransfer time delay shall be immediately bypassed if the emergency power source fails.

E. Controls shall signal the engine-generator set to stop after a time delay, adjustable from 2 seconds to 10 minutes, and factory set at 5 minutes, beginning on return to the normal source.

F. The control system shall include field adjustable provisions to control the speed of transfer of the transfer switch.

G. Power for transfer operation shall be from the source to which the load is being transferred.

H. The control shall include latching diagnostic indicators to pinpoint the last successful step in the sequence of control functions, and to indicate the present status of the control functions in real time, as follows:

Normal Available	Start (Gen Set)	Emergency Available
Transfer Timing	Transfer Complete	Retransfer Timing
Retransfer Complete	Timing for Stop	

I. Provide an exerciser clock to set the day, time, and duration of generator set exercise/test period. The clock shall have battery back-up. Provide a with/without load selector switch for the exercise period.

2.06 FINISH

A. NEMA 1 enclosures shall be painted with the manufacturer's standard light gray ANSI 61 paint.

2.07 ACCESSORIES

A. A momentary test switch shall be provided to simulate a normal source failure.

B. Auxiliary relay contacts shall be provided that are energized when power is available on the normal source.

C. Auxiliary relay contacts shall be provided that are energized when power is available on the normal source.

D. Pre-Transfer Signal Device. The contacts of this device open/close on a timed basis (adjustable 0-120 seconds) to allow the load to be de-energized prior to transfer in either direction.

PART 3 - EXECUTION

3.01 FACTORY TESTING

A. The following standard factory tests shall be performed on the equipment provided under this section. All tests shall be in accordance with the latest version of UL and NEMA standards.

1. Insulation check to ensure the integrity of insulation and continuity of the entire system

2. Visual inspection to ensure that the switch matches the specification requirements and to verify that the fit and finish meet quality standards

3. Mechanical tests to verify that the switch's power sections are free of mechanical hindrances

4. Electrical tests to verify the complete electrical operation of the switch and to set up time delays and voltage sensing settings.

B. The manufacturer shall provide three (3) certified copies of factory test reports.

3.02 INSTALLATION

A. The Contractors shall install all equipment per the manufacturer's recommendations and the contract drawings.

B. All necessary hardware to secure the assembly in place shall be provided by the Contractor.

C. The equipment shall be installed and checked in accordance with manufacturer's recommendations.

3.03 FIELD QUALITY CONTROL

A. Provide the services of a qualified factory-trained manufacturer's representative to assist the contractor in installation and start-up of the equipment specified under this Section for a minimum period of 3 working days or until the installation is completed. The manufacturer's representative shall provide technical direction and assistance to the contractor in general assembly of the equipment, connections and adjustments, and testing of the assembly and components contained therein.

B. The contractor shall provide three (3) copies of the manufacturer's field start-up report.

3.04 MANUFACTURER'S CERTIFICATION

A. A qualified factory-trained manufacturer's representative shall certify in writing that the equipment has been installed, adjusted and tested in accordance with the manufacturer's recommendations.

B. The Contractor shall provide three (3) copies of the manufacturer's representative's certification.

PART 4 – MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Measurement and payment will be made for Automatic Transfer Switch Work of this section, complete in place, with all costs included in the Contract Lump Sum Price for the work as indicated herein.

4.02 PAYMENT

A. Automatic Transfer Switch Work as specified in this Section will be paid for at the Contract Lump Sum Price for Automatic Transfer Switch Work.

4.03 PAYMENT ITEM

Item No.	Item Description	Unit
1626.160	AUTOMATIC TRANSFER SWITCH	LS

END OF SECTION

SECTION 16650

BONDING

PART 1 - GENERAL

1.01 DESCRIPTION

A. This section describes products and installation procedures for furnishing bonding of electrical equipment.

B. The General Documents, as listed on the Table of Contents and applicable parts of Division 1, General Requirements, and requirements of Section 16050, shall be included in and made part of this Section.

C. Related work specified elsewhere:

1. Section 16050 Basic Materials and Methods for Electrical Work

1.02 REFERENCED STANDARDS AND QUALIFICATIONS

A. The following codes and standards apply to work to be performed in this Section and form a part of these Specifications to the extent referenced. The publications are referred to in the text by basic designation only. In case of conflict between provisions of codes, laws, ordinances, and these Specifications, including the Contract Drawings, the more stringent requirements will apply.

1.03 SUBMITTALS

A. Submit the following for approval:

1. Shop Drawings

a. Indicate the arrangements and dimensional locations of bonding cables, and other details.
b. Include manufacturer's literature and data for each proposed product, and installation procedures.

1.04 CERTIFICATION

A. For Certified Exothermic Welding Specialist.

B. For product compliance with these specifications.

1.05 BONDING

A. Bonding provided by this Section is limited to making equipment electrically continuous with low resistance bonds and providing a steel shorting strap, electrically connecting all steel components. Test stations for monitoring pipe corrosion is not included under this Section.

PART 2 - PRODUCTS

2.01 ELECTRICAL COMPONENT MATERIALS

A. Wire Connections: Exothermic cartridge, type and size suitable for the metals being connected using molds, disks, and sleeves as recommended by the manufacturer.

2.03 WIRE

A. Stranded copper, NEC type XHHW or THW, 600 volts, white, black and red insulation as specified.

2.06 WELDING

A. Exothermic, in which the materials to be welded are joined by molten superheated copper produced by reduction of copper oxide by aluminum.

2.07 PIPELINE INSULATING JOINTS - Not Used

2.08 CASING INSULATORS – Not Used

2.09 PADDING TO INSULATE METALLIC PIPE – Not Used

PART 3 - EXECUTION

3.01 INSTALLATION

A. Dielectric Insulators: Install insulating fittings for piping of the type and at the locations shown on the Drawings complete with coating, test wires, and test boxes as shown on the Drawings.

B. Coatings: Clean and prepare all surfaces to be coated and apply all coatings in strict accordance with the manufacturer's recommendations. Apply primers, where required, and coatings to dry surfaces only. Touch up factory applied primers where damaged before application of final coatings using primer identical to factory applied primer. Coat irregular surfaces such as valves, test boxes, fittings, and couplings with coal tar mastic - 30 mils dry film thickness.

3.02 EXOTHERMIC WELDING

A. Clean and remove moisture from surface to be welded, immediately prior to beginning welding operations. Perform welding in accordance with the welding materials manufacturer's instructions.

3.03 WELDS WATERPROOF COATING

A. After approval by the Engineer, cover underground welds with two coats of waterproof coating allowing first coat to thoroughly dry before applying the second coat.

3.04 FIELD QUALITY CONTROL

A. For test station wires, when the exothermic weld has cooled and the slag has been removed, strike the weld with a two-pound hammer around the weld and at an angle of 45 degrees to the surface while pulling on the wire. Remove and replace defective welds.

3.05 BONDING OF UNDERGROUND STRUCTURES - Not Used

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. No separate measurement or payment will be made for Bonding; all cost in connection therewith shall be included in the prices paid for Grounding System Section 16450 to which Bonding pertains.

END OF SECTION

SECTION 16710

FIRE ALARM AND DETECTION SYSTEM

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the furnishing, installing, connecting, testing, and placing in operation a complete analog/addressable fire detection, alarm and control systems with general audio/visual evacuation signaling and voice evacuation in designated areas. The system shall interface to related building systems to conduct monitoring and control functions as described herein.

B. The system shall be a microprocessor-based multiplex control system utilizing distributed processing techniques gather and report data over a network of panels. The network shall consist of a Fire Alarm Control Panel (FACP) and Intelligent Remote Control transponder panels which integrate peripheral devices over the multiplex network. Data communications between panels shall be accomplished through regenerative digital transmission techniques, which enable complete stand-alone or sub-network operation of remote panels in the event of a primary CPU or network communications failure.

C. The system shall have full analog sensing capabilities; will be able to identify the exact location of every sensor and monitored device in the system, and shall operate as described elsewhere in these specifications.

D. The General Documents, as listed on the Table of Contents and applicable parts of Division 1, General Requirements, and requirements of Section 16050 and 16450, shall be included in and made part of this Section.

E. Comply with the applicable requirements of the following:

1. National Electrical Code.
2. Massachusetts Electrical Code.
3. Massachusetts Department of Public Safety.
4. Massachusetts Building Code.
5. National Electrical Manufacturers Association (NEMA).
6. Underwriter's Laboratories, Inc. (UL).
7. American Society for Testing and Materials (ASTM).
8. National Fire Protection Association (NFPA).
9. Institute of Electrical and Electronic Engineers (IEEE).
10. American National Standards Institute (ANSI).
11. Massachusetts Bay Transportation Authority
    Standard Specification FA-1 for Fire Alarm and Detection System, 1996.
12. Boston Fire Department Fire Alarm Order 93-1.
13. Massachusetts Bay Transportation Authority
    System Safety Certification Program Policy FY96.

F. Refer to Division 1, 2, 3, 7, 8 and 15 for special requirements, in addition to those specified in this Section.

1.02 GENERAL REQUIREMENTS

A. Work in this section, as shown or specified, shall be in accordance with the related contract documents.

B. All exceptions, variances and substitutions of operating capabilities or equipment called for in these specifications shall be listed in writing, and forwarded to the engineer at the time of bid. Any exception, variance, or substitutions not listed at the time of bid and identified in the submittal shall be grounds for disapproval without comment.

C. Provide automatic and manual, closed circuit, multiplex fire alarm communications according to the following specifications and as shown on the drawings, wired, connected and left in first class operating condition.

D. Final connections, testing, and adjusting of the system shall be done under the direct supervision of the system supplier. The services of a trained technician employed by the system supplier will demonstrate the system to the satisfaction of the Boston Fire Department and the Authority, and make all additional adjustments to the system operation as required by the Boston Fire Department.

E. The system shall be modular to allow future expansion with a minimum of hardware additions.

F. Provide equipment by one of the following manufacturers:

1. Edwards Systems Technology/FAST
2. Gamewell
3. Notifier
4. Siemens
5. Simplex Time Recorder Co.

1.03 QUALITY CONTROL

A. The system shall comply with the requirements of NFPA 72 and the Boston Fire Department, and shall have all components listed with UL to meet or exceed Standard 167. The reference standards shall be the latest edition of the standards.

B. The devices shall be factory tested under similar conditions to existing site ambient temperature ranges, humidity, and dust.

C. The system design and installation shall conform to the following standards:

1. All equipment shall be UL listed for fire alarm use.
2. NFPA standards 70 (National Electric Code), 72, 90A, 92A, and 101.
3. BOCA (Basic Building Code) - latest edition.
4. Massachusetts State Building Code – latest edition.
5. The Americans with Disabilities Act (ADA).

6. All requirements of the Local Authority having jurisdiction, including Fire Alarm Order 93-1 of the Boston Fire Department.

F. Listing and Labeling: Provide systems and equipment specified in this Section that are listed and labeled.

1. The Terms "Listed" and "Labeled": As defined in the National Electrical Code, Article 100.

2. Listing and Labeling Agency Qualifications: A "Nationally Recognized Testing Laboratory" (NRTL) as defined in OSHA Regulation 1910.7.

G. References:

Factory Mutual Research (FM)

NEMA Guide to Code Requirements for Fire Protective Signaling and Detection Systems

UL 217 Single and Multiple Station Smoke Detection

UL 268 Smoke Detectors for Fire Protection Signaling Systems

UL 864 Standard for Control Units for Fire Protective Signaling Systems

Boston Fire Department F.A. Order 93-1

ADA Americans with Disabilities Act

BOCA National Building Code, Latest Edition

NFPA 70 NEC 2002 Edition

NFPA 72 National Fire Alarm Code, Latest Edition

ANSI/ASME 17.1, Latest Edition

Electrical and Fire Alarm Codes for the State of Massachusetts

NFPA 101 Life Safety Code, Latest Edition

1.04 QUALITY ASSURANCE

A. The equipment supplier and electrical contractor shall have local offices adequately staffed by factory trained engineers and technicians fully capable of providing pre-assembly, testing, instruction, maintenance, and emergency service on all system components.

B. As a condition of acceptance prior to bidding, the equipment supplier and the electrical contractor shall demonstrate a minimum 5 years experience in the successful design and installation of computerized fire alarm systems similar in size and scope to that required.

C. Conform to all UL standards for testing, and provide UL certification of the facility by a certified testing company.

D. The equipment supplier shall conduct the initial programming of the system and a complete rack/test of hardware panels prior to delivery to the installing contractor.

E. Single-Source Responsibility: Obtain fire alarm components from a single source who assumes responsibility for compatibility of system components.

F. Compliance with Local Requirements: Comply with the applicable building code, local ordinances, and regulations, and the requirements of the Authorities having Jurisdiction

1.05 SUBMITTALS

A. Submit 12 complete sets of documentation.

B. Indicate the type, size, rating, catalog number, manufacturer's names, photos, and/or catalog data sheets for all items to assure compliance with these specifications. This equipment shall be subject to approval, and no equipment shall be ordered without prior approval. Equipment devices are shown on the contract drawings.

C. Provide calculations to support the size of standby batteries submitted.

D. Provide a printed description of any special installation procedures.

E. Provide a detailed presentation and description of the system operation.

F. Provide an outline of the required vendor training program.

G. Confirmation that the equipment installer has been factory trained and certified on the particular system to be supplied. Training shall include the proper application, programming and installation procedures for the particular product being supplied.

H. Confirmation that the equipment supplier will provide on-site project management and supervision during system installation, perform system testing, and instruct building personnel on the system operation and maintenance.

I. Provide shop drawings as follows:

1. Complete point-to-point, color-coded wiring diagram which includes all control wiring, device terminations and terminal strip designations required for the fire alarm detection systems as indicated on the plans or described herein. Plans depicting typical installations will not be acceptable.

2. Large scale drawings of the FACP and any remote control panels showing field wiring in full detail.

3. Addresses for all field devices on floor plans and key lists.

4. Include each device type showing manufacturer's recommended mounting and termination method.

5. The system supplier shall review, with the Contractor, the total system point-to-point wiring layout to assure that the correct number and type of wires and conduit sizes are installed. He shall also review the proper installation of each type of device and provide on-site inspection

and supervision as requested by the Electrical Engineer. All final connections, testing and calibrating shall be made under the direct supervision of a factory-trained technician of the system supplier.

6. The shop drawing submittal shall include system lead-time. Lead times in conflict with project scheduling will not be acceptable.

J. Operation and Maintenance Manuals

1. Provide copies of operating & maintenance manuals with the request for final inspection. Manuals shall contain all of the information submitted in the approved shop drawings, and as-built drawings, all manufacturer's drawings incorporating modifications to the system, whether made as a field change or by a change order. Included shall also be a copy of the final test report.

2. As-builts shall include riser and terminal-to-terminal wiring diagrams, schedules showing location and function of each device and specification data sheets. Submittal indicating typical one-line risers and typical specification data sheets only will not be acceptable.

J. Submission to Authorities Having Jurisdiction: In addition to routine submission of the above material, make an identical submission to the authorities having jurisdiction. Include copies of annotated Contract Drawings as needed to depict component locations to facilitate review. Upon receipt of comments from the authorities having jurisdiction, submit them for review. Resubmit if required to make clarifications or revisions to obtain approval.

K. Record of field tests of system.

1.06 SEQUENCING AND SCHEDULING

A. Existing Fire Alarm Equipment: Maintain fully operational until new equipment has been tested and accepted. As new equipment is installed, label it "NOT IN SERVICE" until new equipment is accepted. Remove tags from new equipment when put into service and tag existing fire alarm equipment "NOT IN SERVICE" until removed from the building.

B. Equipment Removal: After acceptance of the new fire alarm system, remove existing disconnected fire alarm equipment and restore damaged surfaces. Package operational fire alarm and detection equipment that has been removed; deliver to Owner. Remove from site and legally dispose of remainder of existing material.

PART 2 - PRODUCTS

2.01 GENERAL

A. Furnish an application program and necessary support hardware for a complete addressable fire alarm system as described herein and as shown on the plans. All components of the entire system shall be listed, labeled, or approved, for its application as fire alarm equipment by NFPA 72, UL, FM, and the local Authority having jurisdiction.

B. The microprocessor-based fire alarm system shall be designed and UL and FM approved for Fire, Audio, Evacuation and Security applications. The system operational characteristics shall be stored in non-volatile EEPROM memory, and the entire Input/Output and control function shall be field programmable and capable of being edited with no factory involvement.

C. Data communications between the main FACP and remote panels shall be via type 7 regenerative communications. In the event of a loss or failure of the primary CPU located at the FACP, all remote panels shall continue to perform their respective detection, annunciation, signaling, and/or control functions on a stand-alone or sub-network basis.

D. The system shall support analog sensing techniques to monitor individual devices enabling the user to manually or automatically change the sensitivity parameters in accordance with design and application requirements. All inputs shall be subject to multi-level alarm verification. The system shall be capable of displaying status of the sensor by device and/or traditional input and vectoring the value to a printer. The system shall automatically identify any analog sensor which becomes dirty (maintenance alert), prior to false alarming.

E. The system shall be supported by standby batteries. In the event of a loss of primary power, batteries shall support 60 hours of full supervisory operation followed by 5 minutes of alarm.

F. An integral real time clock will provide time control functions including day of week programming to schedule control of detector sensitivity and alarm functions. The system shall be capable of nine levels of alarm prioritization, and allow control by event, and may include cross zoning, stepping, and/or logic statement inputs.

G. The Fire Alarm Control Panel (FACP) shall provide the overall system monitoring, testing, display, reporting, and firefighter controls to override automatic actions. The FACP shall provide the following functions:

1. Monitor all initiating devices, annunciate the alarmed device and its' location, notify the local authority, capture elevators, transmit signals to activate smoke control functions, and initiate audio/visual evacuation signaling.

2. Initiating devices shall respond with their condition. Control relays shall be individually addressable by the system to respond automatically in the event of an alarm of related sensors.

3. Manual override of control relays shall be individually addressable by the operator.

H. All equipment shall be new and unused. All components and systems shall be designed for uninterrupted duty. All equipment, materials and accessories covered by these requirements shall be provided by a single manufacturer, or if provided by different manufacturers recognized as compatible by both manufacturers.

I. All reference to manufacturer's or supplier's model numbers and other pertinent information herein are supplied to establish minimum standards of performance, function and quality. Equivalent equipment from other manufacturers may be substituted for that specified. In order to be considered as an alternate, the equipment shall be approved by the engineer prior to bidding.

J. The model numbers used are those of Edwards Systems Technology/FAST and constitute the quality and performance of the equipment and system to be furnished.

K. Circuiting Guidelines. Each manual or automatic detection device or circuit shall be individually addressable. Circuit wiring shall be as follows:

1. Addressable monitor modules shall be used for waterflow, tamper, or any other status indications from related subsystems.

2. Addressable loop wiring shall allow for 25% spare capacity.

3. Addressable control modules shall provide auxiliary control functions.

4. Audible circuits shall be addressable at 2 circuits per floor (minimum) with a minimum of 25% spare capacity.

5. ADA strobe circuits shall operate all strobes shown plus 25% spare capacity.

6. Audible and visual signals shall be on separate circuits to allow silencing of the audible signals while maintaining an active visual signal.

2.02 SEQUENCE OF OPERATION

A. The operation of a manual station or activation of any automatic alarm initiating device (smoke, heat, waterflow) shall automatically:

1. Sound all audible devices throughout the building until silenced at the Fire Alarm Control Panel or until the horn timer has elapsed. The "ON" period of the timer shall be as selected by the Authority.

2. Flash all visual signals throughout the building until the system has been reset at the FACP.

3. Activate a pre-recorded voice message in designated areas. Orderly evacuation of the designated areas shall be conducted via a dedicated audio control panel.

4. Flash a red alarm LED and sound an audible signal at the FACP. Upon Acknowledgment, the alarm LED shall light steadily and the audible shall silence.

5. Recall all elevators that serve the floor of initialization to the ground floor. If the alarm initiates on the ground floor, return the elevator to the floor above or as directed by the local authority having jurisdiction.

6. Visually indicate the addressable device or the circuit of alarm initiation via the 80 character LCD display at the FACP and any corresponding remote panels.

7. Visually annunciate on the system annunciator(s), the zone, floor, or area as required.

8. Provide local power to the City Fire Alarm Master Box.

9. Automatically shut down HVAC systems as required.

10. Operate prioritized outputs to release all magnetically held smoke doors and magnetically locked doors throughout the building.

11. Activate the exterior strobe/beacon.

B. In addition to the above paragraph, operation of any sprinkler water flow indicating devices shall cause the sprinkler zone to be alarmed.

C. Alarms shall lock-in until both the initiating devices have been restored to normal and the system control unit is reset. Alarm may be silenced but subsequent alarms from another zone shall cause the

alarm to resound. When the horns are silenced, a system trouble signal shall be indicated.

D. Any fault or disarrangement of the system shall cause the trouble signals to operate. The audible trouble signal may be silenced by operating a momentary silencing switch, but the visual trouble signal shall remain lighted. After the fault has been corrected, the trouble circuit shall automatically restore to normal. All remote trouble indicating devices shall operate identically, including the self-restoring feature. Faults on any zone shall cause an individual zone trouble indicator light. Control unit shall include a momentary lamp test switch which shall light all visible indicators in the control unit when operated. System shall indicate trouble when horns are silenced and alarm circuits are in non-alarm condition.

E. Failure Indications

1. A break in any detector loop wiring shall light the respective zone trouble light and send a trouble indication via the autodialer/CPLC to 45 High Street. The same trouble indication shall also be sent for AC power failure, ground fault audible and visual alarm circuits, municipal trip disconnect fault and low battery.

2. Provide the Authority with necessary hardware and software interface for existing computers to provide an overall functioning system. Remote indications to 45 High Street shall be via the autodialer/CPLC.

F. Fire Alarm Remote Transmission

1. Interface output of fire alarm control panels to the autodialer to be located in the Fire Control Panel and the CPLC located in the Communication Room. Fire alarm and trouble conditions are to be transmitted to 45 High Street.

2. The Contractor shall be responsible for:

a. Installation of interface cable from Fire Alarm Control Panel to the autodialer as well as cable requirements to the telephone demarcation and interface to the CPLC.

b. All software data entry at the receiver headend, and interface requirements at 45 High Street.

c. Upon loss of operating power, the system shall light a power trouble condition lamp, indicate a trouble condition, and automatically transfer to battery standby. Battery set shall be sealed lead acid or lead cadmium sufficient to operate the system for at least 60 hours followed by 5 minutes of alarm. Upon alarm, the outdoor beacon shall operate under battery standby conditions. Contractor shall include both a standby load and alarm load chart with shop drawings to indicate compliance with this paragraph.

d. All gate and OS&Y valves shall be monitored by appropriate supervisory switches. Operation of a supervisory switch shall not cause an alarm signal, but shall cause a special distinct, audible supervisory alarm. Any fault or disarrangement of the supervisory loop system shall cause a supervisory trouble signal to operate. A separate zone shall be used for sprinkler system supervision.

2.03 SYSTEM COMPONENTS

A. Fire Alarm Control Panel: Provide and install an EST/FAST IRC-3 Fire Alarm Control Panel. The

FACP shall be capable of supporting up to 52 remote panels over a single line network. The system may consist of 3000 supervised analog/addressable devices over 16 addressable loops. Fiber Optic and 20ma loop data interface options shall be available.

B. Control Configuration: The main fire alarm control portions of the system shall be housed in a locking, semi-flush mounted enclosure. The enclosure shall be 14 gauge steel printed red, with pin and tubular-type lock provided with six (6) sets of keys. Enclosure shall be marked "FIRE ALARM CONTROL PANEL" with 2" letters, white on red. Panel trim shall be red. Lock shall be keyed the same as manual stations. All panel initiating and control status indicators shall be visible through a clear Lexan window. The FACP shall incorporate a primary CPU, power supply/batteries, annunciation and the required switch functions to provide the system operation as described. The main CPU shall have the necessary firmware to provide via software programming the following:

1. Logic statements/stepping alarm functions
2. Weekday/Holiday schedules
3. Analog sensitivity reporting
4. System sensor maintenance alerts
5. Individual sensor sensitivity adjustments
6. Day/night sensitivity adjustments
7. Alarm verification by point or zone
8. Alarm verification activity report
9. On demand system status printout
10. Normal and silent walk test
11. 800 event history log and printout

C. Remote Graphic Annunciator Panel:

1. A remote fire alarm annunciator panel shall be provided and installed where shown on the Contract Drawings, or as instructed by MBTA.

2. The annunciator shall be electrically supervised, if not, include a lamp test switch. Annunciator shall be lighted to indicate the zone and remain lighted until extinguished by reset of the FACP. The unit shall have a graphic display depicting the building layout, divided into appropriate zones, clearly label with zone number and code number, if any in each area. Each zone shall be back lit to indicate fire. Trouble may be displayed by a common visual and audible signal. All room number and designations shall be coordinated with the actual door designation.

3. Layout shall have approval from Local Authority prior to installation.

D. Auxiliary Control/Annunciation: Provide serial annunciator (SAN) matrix switch and LED status panels for zone disconnect, HVAC override, and other related override functions. These are intended for use by the Fire Department during an event, or by authorized personnel during testing periods. Keypad entered commands for these functions shall not be an acceptable substitute. Zone disconnect shall be provided by type of device on a per floor and/or zone basis.

E. Power Requirements

1. The control panel shall receive 120V AC power (as noted on the plans) via a dedicated circuit breaker from an emergency power panel.

2. The system shall be provided with sufficient battery capacity to operate the entire system upon

loss of normal 120V AC power in a normal supervisory mode for a period of 60 hours with 5 minutes of alarm operation at the end of this period. The system shall automatically transfer to the standby batteries upon power failure. All battery charging and recharging operations shall be automatic.

3. 120V AC primary power shall be monitored and a "Power-On" lamp shall be provided. Upon power outage the system shall light a power trouble condition lamp, indicate a trouble condition and automatically change to standby batteries. The control panel shall also monitor the batteries and, upon a low battery condition, light the low battery lamp and indicate a trouble condition. Fire system ground detection shall be provided for the alarm system. Upon ground detection, the ground detection lamp shall light and a trouble signal indicated. Provide a lamp test switch to test all lamps on the control panel.

4. Additional Power Supply Features:

   a. Automatic/demand battery charger circuit
   b. Lead acid and nicad compatible
   c. Instant transfer to battery upon thermal overload
   d. Relay outputs for Alarm, Trouble and Supervisory status.

F. System Power Supplies: The system power supply(s) shall provide 24Vdc operating and emergency power to the system. The supply shall be a minimum 80% efficient, switch mode solid state design, with built-in maximum transient protection (up to 6 KV) including UL recognized EMI filter, spark gaps, tranzorbs, and varistors. Power supply(s) shall provide up to 7.0 amps of filtered, regulated, power limited 24Vdc. They shall contain brownout, low battery detection, system ground fault, and LED indicators for loss of AC or CPU failure, and be capable of charging up to 60 AH batteries.

G. Intelligent Remote Control/Transponder Panels (If Required):

1. The main CPU shall poll intelligent remote FACP/transponder panels over a regenerative multiplex communications network. Each remote panel shall be capable of supporting up to 576 analog devices and shall have Reset, Alarm Silence, and Trouble Silence switch functions.

2. In the event of a loss of communications with the primary CPU, the remaining interconnected remote panels will automatically form a sub-network and switch to stand-alone mode. In stand-alone mode, the remaining panels will continue to perform their respective detection, annunciation, signaling and control functions.

3. Each remote panel shall contain the following:

   a. Non-volatile EEPROM memory

   b. Real-time clock

   c. Field programmable software with the capability to load, edit, or change locally or remotely using modems through a self-contained RS-232 communications port.

   d. Dedicated power supplies and batteries.

   e. An LCD display (80 character display required for remote FACPs) to indicate all alarms activated by devices connected to the particular panel.

H. Intelligent System Devices: Provide intelligent sensors as shown. The device address shall be dial selectable by the installer. All intelligent sensors shall require 2 wires be connected to the addressable loop except where noted. All devices shall incorporate built-in type identification so the system will automatically identify various types of sensors. Sensors shall utilize LED indicators which flash during an active polling cycle, and light steadily when in an alarm condition. All common types of analog sensors shall be interchangeable with common twist-lock bases where applicable. Analog sensors shall provide indication to the control panel that a detector requires maintenance.

1. Analog Photoelectric Sensor: Analog photoelectric smoke sensors (EST Model 2551F) shall be continually monitored to measure any change in their sensitivity because of the environment (dirt, air temperature, humidity, etc.), and shall allow changes in sensitivity levels within the UL approved sensor's range.

2. Analog Thermal Sensor: Analog thermal sensors (EST Model 5551F) shall be continually monitored to measure any change in their sensitivity because of the environment (dirt, air temperature, humidity, etc.). The sensor shall use dual solid-state thermistors and shall monitor the ambient temperature from (-) 10 degrees Celsius to (+) 60 degrees Celsius, and provide fast response to rapid increases in temperature. Where required, provide conventional Heat Detectors in lieu of analog thermal sensors. Conventional heat detectors shall operate on fixed temperature and rate-of-rise operating principles, and shall have the proper temperature rating. Each heat detector shall be individually addressable via an M500MF Monitor Module.

3. Analog Duct Smoke Sensor:

   a. Provide analog photoelectric duct smoke sensors (EST Model DH 500) where required. Each sensor shall be supplied with a remote test and indicating station and sampling tube sized according to duct width.

   b. The remote test and indicating stations shall be wall-mounted adjacent to the duct detector at 6'-0" A.F.F. in an area where it will not interfere with cabinets, shelves, doors, etc. The stations shall have normally open alarm contacts from connection to the alarm initiating circuit and one set of SPDT contacts rated at 2 amps 30 VDC and 0.5 amps 125 VAC.

   c. The detector housing shall be a metal enclosure suitable for ductmounting. The unit's sampling tubes shall extend at least threequarters (3/4") inch diameter. Each inlet sampling tube shall have a half-inch by one inch (1/2" x 1") cut-out one inch (1") from the end of the tube, with one-quarter inch (1 /4") diameter holes for the length of the sampling tube to provide complete crosssectional, large volume air sampling.

4. Manual Stations: Provide addressable manual stations (EST Model 278B) where shown. The station shall be double action type with screw terminals and an integral toggle switch. The station shall be constructed of red Lexan with white raised letters, a key reset switch and an optional break glass rod. The station shall be keyed alike to the fire alarm panel. The manual station shall be used in conjunction with the M501MF nitor module. The station shall mount to a standard single gang switch box or to a red backbox for surface mounting. Where required, provide a Stopper 2 clear Lexan cover for each manual station.

5. Monitor Module: Provide addressable Monitor Modules (EST Model M500MF, or M501F) to connect individual supervised conventional initiating devices onto the addressable loop. In order to maintain Class A supervised wiring, no T-taps will be allowed.

6. Intelligent Control Module: Provide Control Modules (EST Model M500CF) to supervise and control conventional devices (indicating, air handling, and door holder, etc.) over the addressable loop. Control modules shall provide a supervised output rated at 1 amp @ 24V DC.

7. Isolation Module: Provide Isolation Modules (EST Model M500XF) to protect the integrity of analog circuits by isolating intelligent devices in the event of a short circuit or a loss or degradation of the data signal. Provide one isolation module for every 25 devices on each addressable loop.

E. Primary Notification Appliances: Flush mounted combination Audio/Visual signaling appliances shall be provided. Standalone devices may be used to augment combination units when necessary. Devices shall have minimum outputs as required by ADA guide lines. Specific audible and visual characteristics shall be as follows:

1. Visual Signals: Furnish and install (LSM series) xenon strobes as shown in compliance with the Americans with Disabilities Act. Visual signals shall have a minimum effective intensity rating of 75 candela.

2. Audible Signals: Furnish and install flush mounted re-entrant speakers where shown and required. Speakers shall be red with adjustable power taps of .25, .5, 1, and 2 watts. Frequency response shall be 400 to 4,000 Hz with an 85 dB sound level @ 1W RMS, or 15 dB above ambient, whichever is greater @ 10' on axis. Provide surface mount backboxes where required.

F. System Accessories

1. Auxiliary Audio Control: Provide a dedicated audio control system complete with microphone, amplifier and speakers where shown in designated areas of assembly.

2. System Printer: Provide a supervised Event Printer (EST Model PT1). The event printer shall print out all status changes, messages, reports and event histories. The printer shall be a dot matrix printer with a 200 CPS print speed and be capable of serial or parallel communication with the FACP or any remote panel. Printers shall be powered by local 110V AC, and uninterruptible power supplies are required.

3. Remote Graphic Annunciator(s): Provide a remote graphic annunciator(s) where shown on the plans, depicting the number of zones shown in the drawings. The annunciator shall incorporate alarm and trouble LEDs for each zone according to the zone schedule. The display shall depict the building layout as represented on the floor plans, and the annunciator shall be approved by the engineer and the Boston Fire Department prior to construction.

4. Auxiliary Strobe Power Supplies: Where required, provide distributed power supplies to accommodate the power requirements of visual strobe circuits. Each supply shall be UL listed, electrically supervised and be subject to battery backup.

5. Terminal Cabinets: Provide fire alarm terminal cabinets where necessary. The cabinets shall have a removable hinged cover with key lock and are intended to house monitor and control modules, and facilitate field wiring junctions. Terminal cabinets shall have a red finish with permanent white labeling.

6. Remote Alarm Indicators: Provided remote LED indicators for sensors located behind locked doors. Provide a label on each indicator identifying the device's actual location.

7. Exterior Strobe: Provide a flashing weatherproof beacon with a minimum 150,000 candlepower output where shown. The strobe shall be properly installed to a weatherproof backbox.

8. Wire Guards: Provide protective guards over automatic detectors and signal devices where shown on plans.

9. Door Holders: Magnetic door holders shall be furnished and installed under Section 08710. Door holders shall be wired under this Section. Door holders shall be rated for 110 volts. Provide sufficient power capacity in control panel for all door holders.

10. High Security Key Control Lockboxes: Provide a key control lockbox, recessed mounted, at locations shown on plans. Boxes shall be manufactured of ¼" plate steel housing, 5/8" thick steel door, capacity of 60 cu. in. Exterior dimensions are 7"W x 7"H x 5"D. Boxes shall have interior gasket seal of neoprene material, 1/8" stainless steel lock cover with tamper seal mounting capability. Boxes shall have anti-theft relocking mechanism with drill resistant hardplate lock protector. Steel finish pretreatment of zone-phosphate to Federal Standard TTC 490 Type II. Final coating shall be weather-resistant polyester powder coat, interior and exterior. Lock shall have double-action rotating tumblers and hardened steel pins, accessed by a bias-cut key. Boxes shall be equipped with contacts that will indicate trouble at the "FACP" if box is opened. The FACP construction shall comply with UL 864.

11. Locks and Keying: All locks for fire alarm equipment shall be keyed to conform to Boston Fire Department's and the Authority's keying system.

2.05 MASTER BOX

A. Provide an approved master fire alarm box, local energy type with the local Authority having jurisdiction.

B. The fire alarm master box will automatically notify the local fire department by transmitting the appropriate code when any automatic or manual initiating device for the station is actuated or when the box is manually of remotely tripped. The master box shall be located as shown on the plans and the color shall be as required by the local Authority having jurisdiction.

C. Provide cable from the master box to a connection point as designated by the local fire department or by the local authority having jurisdiction. The Contractor shall coordinate the cable installation with the local fire department. Cable requirements shall meet the requirements of the International Municipal Signal Association Specification 19-5 (latest edition).

D. Master box shall be coded local energy type as approved by the local fire department. It shall also include a box microswitch which shall operate from the manual pull lever when located in the protected area not subjected to the general public, to operate the local system. Cutting of code wheel and timing shall be the responsibility of the Contractor.

E. Master box shall be covered during construction to prevent accidental use and remain covered until the municipal connection is completed and the system is approved by the Superintendent of Fire Alarm.

F. The Master box shall be an approved, local energy type with Boston Fire Department lock.

G. Shunt type Master boxes are not allowed.

H. The Master box trip circuit shall be supervised and its status shall be annunciated at the Central Control

Panel and through the system trouble indicator at the remote annunciator.

I. The Master box shall be located inside the building as directed by the Superintendent of Fire Alarm.

J. The Master box shall be equipped with the necessary means to permit it to act as a manual station on the building alarm system. In non-coded systems it shall be annunciated separately. In coded systems it shall be operated by its own specifically coded transmitter.

2.06 AUTOMATIC TELEPHONE DIALER/TRANSMITTER/CPLC INTERFACE

A. The Fire Control Communicator shall be provided for 120 volt a-c operation and shall contain a 12 volt, 7 ampere-hour rechargeable battery capable of operating the unit for up to 60 hours during a power failure, and charger for the battery. The Communicator shall be fully supervised, microprocessor type and shall monitor the zone inputs, a-c power, the standby battery, and the telephone line connections. If the unit detects a fault condition, it shall sound a local audible signal and it shall transmit the condition over the telephone lines to the OCC. The unit shall provide for connection to two redundant telephone lines, and in the event of a telephone line fault, the unit shall automatically transmit over the remaining line. The unit shall be UL 864 listed for use in NFPA 72 Central Station and Remote Supervising Station Fire Alarm System service. It shall provide automatic self test by sending a report to the OCC every 24 hours. It shall be capable of reporting in the major communications formats. The Fire Control Communicator shall be as manufactured by Silent Knight, Model 5104, or equal. In addition, N.O./N.C. contact points for fire alarm trouble and fire alarm activation shall be wired to the Communication Logic Controller located within the Communication Room. These points shall activate upon fire alarm trouble or fire alarm activation which shall report these conditions to 45 High St. via the CPLC interface.

2.07 SPRINKLER SYSTEM(S) ALARM & SUPERVISORY SWITCHES

A. All sprinkler system(s) alarm and supervisory switches furnished and installed under Section 15500, fire protection, shall be wired to the fire alarm system as a separate dedicated zone by the Contractor.

B. All sprinkler supervisory switches, low water pressure switches, and flow switches shall be wired to the fire alarm and data monitoring systems.

C. All materials and equipment necessary for the complete installation of dry and/or wet automatic sprinkler systems shall be furnished in accordance with the latest standards of the National Fire Protection Association, the local authority having jurisdiction, and the MBTA.

D. Wet Automatic Sprinkler System

1. For a wet pipe system alarm pressure switches shall be pressure type, water flow detectors in the alarm port of the sprinkler check valve.

2. Alternatively, wet vane type water flow detectors shall be installed on the sprinkler system piping. Detector shall be designed for mounting on either vertical or horizontal piping, but shall not be mounted in a fitting or within 12 inches (12") of any fitting that changes the direction of the water flow, and shall have a sensitivity setting to signal any flow of water that equals or exceeds the discharge from one sprinkler head. Detector switch mechanisms shall incorporate an instantly recycling pneumatic retard element with an adjustable range of 0 to 70 seconds. Switches shall be actuated by a polyethylene vane extending to the waterway of the piping..

3. Pressure switches shall have adjustable two-stage ranges. Switches shall be provided with two

half-inch (1/2") conduit entrances and a quarter-inch (1/4") female NPTF pressure connection. Minimum switch contact rating of 15 amps, 110 VAC, 0.25 amp, 110 VDC no alarm switches shall be allowed on the retard chamber except for the operation of a local electric device. All water flow detecting devices shall be equipped with a retard timing feature except when an excess pressure pump is used.

4. A low pressure alarm switch shall be installed on the system side of the sprinkler check valve which, when operated, will indicate an alarm with no water flow.

5. A low pressure alarm supervisory switch shall be installed on the supply side of the sprinkler check valve which, when operated, shall indicate no or low water pressure and give a special signal to the FACP.

E. Dry Automatic Sprinkler Systems

1. For dry pipe systems, an alarm pressure switch shall be installed in the alarm port of the sprinkler check valve which, when operated, will send an alarm to the FACP indicating water flow.

2. A low pressure alarm switch installed on the system side of the sprinkler check valve which, when operated, shall send an alarm to the FACP indicating no or low air pressure in the system and no water flow.

3. There shall be two supervisory low pressure switches, one installed on the system side of the sprinkler check valve which, when operated, will send a special signal to the FACP indicating low air in the system and the possibility of the system filling up with water. The other low-pressure switch shall be installed on the supply side of the OS&Y valve which, when operated, will send a special signal to the FACP indicating low or no water supply.

4. Tamper switches shall be installed on all main OS&Y and shut-off valves of each system. Tamper switches shall be installed so as not to interfere with the normal operation of the valve and shall be adjusted to operate within two revolutions of the valve control stem. The switch shall be mounted in a weatherproof enclosure, which will provide for one-half inch (1/2") conduit entrance or larger. The switch shall be supplied with all hardware and brackets required for mounting as recommended by the manufacturer. The switch mechanism shall have a rated capacity of 5 amps at 125 VAC, 0.25 amps at 125 VDC. The unit shall be designed to cause a switch operation if the valve is closed. The electrical contractor shall wire the switch into the Fire Alarm Control Panel in a manner that would initiate a special signal if the switch mechanism is operated. The special signal given by the supervisory devices shall be a signal different than that used for a wiring defect.

2.08 CABLE FOR MUNICIPAL CONNECTIONS

A. Cable shall be furnished and installed from the Master box to a connection point in the municipal fire alarm system designated by the Superintendent of Fire Alarm. The contractor shall supply all necessary cable and hardware for such connection. The installation shall be done by the Boston Fire Department.

B. All connections to the municipal fire alarm system shall be made by the Boston Fire Department.

C. Cable for the underground service shall meet the requirements of Specification 19-5 of the International Municipal Signal Association (IMSA), i.e., polyethylene insulated, polyethylene belted, copper shielded, PVC jacketed signal cable.

D. The underground cable outer jacket shall be red.

E. Cable entering building from underground may use existing duct work of the Verizon Company to enter the building. If such duct is not available a minimum three (3) inch duct shall be installed as directed by the Superintendent of Fire Alarm. Such duct work shall be Schedule Heavy Wall 40 PVC duct encased in concrete.

F. All cable containing municipal fire alarm circuits in the building shall be enclosed in an approved raceway. All junction/pull boxes for this cable shall be painted red. A red two (2) inch wide stripe shall be placed on this raceway every ten (10) feet. The covers of the boxes shall be labeled "Municipal Fire Alarm Circuit".

G. A ground connection shall be installed from the ground terminal of the Master box to the electrical equipment ground of the building using a green #4 AWG THHN wire minimum. A ground strap shall also be installed between the ground connection and the shell of the box.

H. The IMSA cable manufacturers shall be Belden, Rome-BSC or approved equal.

I. The IMSA cable for municipal connection shall be signal cable 600V rating, solid bare copper, four (4) # 14 AWG conductors, polyethylene (PE) insulation, color coded per IMSA straight conductor, straight lay (not twisted pairs), copper tape shield between jackets, polyethylene (PE) inner jacket, polyvinylchloride (PVC) outer jacket.

PART 3 - EXECUTION

3.01 GENERAL

A. Installation shall be supervised and tested by the system supplier. The work shall be performed by skilled technicians under the direction of experienced engineers, all of whom shall be properly trained and qualified.

3.02 INSTALLATION

A. All wiring for the system shall be in accordance with Articles 760, 725, and 800 of the National Electrical Code and local electrical codes.

B. Provide complete wiring and conduit between all equipment. All devices shall be mounted upon and terminations made in terminal cabinets. Wiring splices and transposing or changing of colors will not be permitted.

C. All wiring types and sizes shall be as follows or as otherwise required by the equipment manufacturer:

1. Addressable loop and Network communications shall be via a #16 non-shielded twisted pair with six twists per foot (Belden #9572 or equal).

2. Signal circuits shall utilize #16 THHN.

3. All notification circuits shall be two (2) hour rated cable.

D. Fire Alarm control systems and equipment shall be connected to separate dedicated branch circuits, sized as required for proper service. Circuits shall be labeled 'FIRE ALARM'.

E. Install all wiring in rigid steel conduit. All conduits containing fire alarm conductors shall have a two inch (2") red stripe placed on the conduit every ten feet. Covers of pull and junction boxes shall be painted red and labeled **"FIRE ALARM".**

F. Paint outside of each pull box with flame retardant red paint.

G. Identify all conductors by color and listing as function.

1. Color code all fire alarm initiating and alarm device wiring as follows:

a.	Smoke detector power:	D. C. positive	Orange
		D. C. negative	White
b.	Initiating circuit:	Alarm wires	Red
		Supervisory wires	Blue
c.	Alarm circuit:	Alarm wires	Yellow
		Supervisory wires	Blue

H. Install all end-of-line devices in the Fire Alarm Control Panel.

I. Install a red rotating beacon light on the building which shall be activated by alarm actuation within the building. Location shall be coordinated with the Boston Fire Department.

J. Install red fire box indicating lights above each outdoor pull station, continuously illuminated.

K. When required, furnish and install a remote trouble alarm (sonalert) and flashing light unit with silence switch. Beneath trouble light, furnish and install a noncombustible sign with three-quarter inch (3/4") letters designating trouble alarm appropriate phone number to be called or fire alarm service. Locate unit as shown on plans.

L. Electrical rooms, battery rooms, elevator machine rooms, generator rooms, commercial areas and substation rooms shall have detectors with remote alarm indication.

M. Install fire alarm cable from master box to point of connection in accordance with all Boston Fire Department requirements.

N. Furnish and install the circuit breaker lock on all circuit breakers providing power to the fire alarm system. The lock shall be painted the same color red as approved for all pull boxes. Also, inside the FACP, identify the AC circuit breaker feeding the FACP by a permanent tag.

O. The Contractor shall coordinate with the local fire department and schedule and obtain all required system connection and testing. Contractor shall pay all back charges and fees as required by the Boston Fire Department.

P. The Contractor shall mark or permanently identify each fire alarm device with the same identification code established by the manufacturer in the construction plans. The identification of each device shall also appear on the as-built drawings.

Q. All pull stations shall be identified with lamacord name plates engraved on a red face with white letters and numbers.

R. All other devices: horns, smoke detectors, duct detectors (remote indicator), etc., shall be identified with an indelible ink. Heat detectors shall be identified on the base and not on the detector head.

S. The sequence of devices on each zone shall be manual alarm stations first, zoned water flow, switches second, heat detectors third, other initiating devices fourth, smoke/heat detector combinations fifth, and tamper switches electrically last.

T. Identification of all devices must be completed before final inspection by the Authority.

U. The Contractor shall provide a No. 14 AWG copper ground wire in three-quarter inch (3/4") conduit from the master box to the street side of the main water shutoff valve.

V. As areas of the station are demolished contractor shall remove and dispose all existing fire alarm equipment, including cable and conduit, to existing panelboards, Fire Alarm Control Panel (FACP), and Annunciator. Equipment shall be disposed in compliance with owner's discretion.

W. Contractor shall install fire alarm equipment in areas being renovated and temporarily energize equipment and maintain operability of equipment until demolition ends and new construction presents the opportunity to install new equipment.

3.03 GROUNDING

A. Ground cable shields and equipment according to system manufacturer's instructions to eliminate shock hazard and to minimize, to the greatest extent possible, ground loops, common mode returns, noise pickup, cross talk, and other impairments.

B. Signal Ground Terminal: Locate at main equipment rack or cabinet. Isolate from power system and equipment grounding.

C. Install grounding electrodes of type, size, location, and quantity as indicated. Comply with installation requirements of Division 16 Section "Grounding."

D. Ground equipment and conductor and cable shields. For audio circuits, minimize, to the greatest extent possible, ground loops, common mode returns, noise pickup, cross talk, and other impairments. Provide 5-ohm ground at main equipment location. Measure, record, and report ground resistance.

3.04 TESTING

A. Each, device shall be tested in the presence of a manufacturer's representative. Upon completion of the test, a certified test report shall be submitted for approval.

B. Any system deficiencies observed under testing shall be noted in the certified test report. All deficiencies shall be corrected and all systems shall then be retested.

C. Test complete system with the Authority as required by the local fire department. If any deficiencies are observed, correct same as described herein.

D. Drawings and Diagrams

1. Contractor shall submit as-built drawings, operating and troubleshooting manuals, before scheduled testing by the Authority.

2. As-built drawings will be dedicated fire alarm system drawings only (no other systems shall be shown).

3. The drawings shall be prepared in Computer-Aided Drafting Design (CADD) format acceptable to the Authority. Data will be submitted concurrently in both hard copy and machine readable digitized format on CD ROM.

4. Plans and drawings will be submitted and shall include, but is not limited to, the following:

   a. Site and floor plans identifying and showing the location of all devices, combinations of devices and equipment installed, including conduits and junction boxes.

   b. Point-to-point wiring diagrams showing color coded wire tag notations and terminal strip designations at the devices and controls.

   c. System riser diagrams.

   d. Control panel wiring diagram showing all external connections to the modules.

E. Manuals

1. Operating and troubleshooting manuals shall contain:

   a. Component replacement instructions, including internal parts.

   b. Cleaning and testing equipment and schedules.

   c. List of all equipment/component information such as addresses, telephone numbers of manufacturers and local suppliers.

   d. Step-by-step operating instructions for the control panel and system.

F. Final acceptance of the fire alarm system shall be conducted by the local fire department in the presence of the Authority, the Contractor and the manufacturer's representative on a date established by the local fire department and the Authority. Final Test Notice: Provide a 10-day minimum notice in writing when the system is ready for final acceptance testing. Minimum testing procedures shall be in accordance with the procedures outlined in NFPA 72.

G. Prior to final acceptance of the system, furnish a one-year written service contract with an authorized service representative of the manufacturer of the equipment commencing with guarantee start, for maintenance inspection and the service of the equipment with a minimum of one inspection and service of the equipment every three months within the contract period.

1. Inspection shall include testing of the complete system and making all required adjustments to the system. A report of each test shall be forwarded to the MBTA Engineer, which shall include the following information:

   a. Date of test.
   b. Name and location being tested.
   c. Master fire alarm box number.
   d. Number of devices requiring adjustment.

e. Number of interior alarm circuits.
f. Condition of emergency standby power supply.
g. Name of company conducting test.
h. Names and signatures of persons conducting test.
i. License number of person conducting test.

H. The Test Technician

1. Systems shall be tested under the supervision of a responsible, qualified person or organization satisfactory to the Boston Fire Department, who shall, under contractual agreement, make all inspections, tests and repairs promptly. Said person or organization shall comply with all applicable state laws, licenses, ordinances, rules or regulations and shall hold a Certificate of Competency issued by the Licensing Division of the Inspectional Services Department of the City of Boston, with an F-1 endorsement for direct municipal or Central Station connections and be listed by Underwriters' Laboratories to provide the UL certificate service. The organization supplying final checkout and contractual service and testing will provide the Underwriters' Laboratories field certification of installation for any new system.

I. Testing Company

1. The approved testing company must submit a letter attesting to a 100% acceptance test of the building. This letter shall be prima facie evidence that the system is ready for Fire Department inspection.

2. The Contractor shall pay all testing fees, as well as any subsequent fees resulting from retesting, if required.

3.05 WARRANTY

A. Manufacturer shall guarantee all system equipment for a period of one year from the date of final acceptance of the system.

B. The contractor shall guarantee all raceways and wiring to be free from inherent mechanical or electrical defects for one year from the date of final acceptance of the system.

3.06 TRAINING

A. The contractor shall provide the services of a qualified manufacturer's representative for a period of 4 hours, during normal business hours, to instruct the owner's designated personnel on the operation and routine maintenance of the system.

3.07 ON-SITE ASSISTANCE

A. Occupancy Adjustments: When requested within one year of date of Substantial Completion, provide on-site assistance in adjusting sound levels, controls, and sensitivities to suit actual occupied conditions. Provide up to 3 requested adjustment visits to the site for this purpose.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Separate measurement and payment will not be made for Fire Alarm and Detection System Work of this

Section, complete in place, but all costs shall include in Contract Lump Sum Price for the Work as indicated.

4.02 PAYMENT

Fire Alarm and Detection System Work as specified in this Section will be paid for at the Contract Lump Sum Price for Fire Alarm and Detection System Work.

4.03 PAYMENT ITEMS

Item No.	Item Description	Unit
1651.200	FIRE ALARM SYSTEM	LS

END OF SECTION

SECTION 16711

TELEPHONE INSTRUMENTS

PART 1 - GENERAL

1.01 DESCRIPTION

This Section specifies furnishing, installing, connecting, testing and placing in operation Telephone Instruments. All communications equipment, hardware, and ancillary devices required, as described or implied herein and shown on Contract Drawings, shall be the responsibility of the Contractor.

1.02 QUALITY ASSURANCE

A. Submit proposed manufacturer of telephone instruments and ancillary equipment to the Engineer for approval. All equipment shall be new and unused. Past performance and experience will be factored in evaluating each proposed manufacturer, in part. Additional criteria will be:

1. Quality and capability of equipment.
2. Manufacturer Support.
3. Technology used system flexibility, and features.
4. Ability to furnish and install within required time frame.

B. Manufacturer shall provide a one-year warranty on all equipment furnished and installed. Contractor shall maintain this warranty, extending to system acceptance or one year after equipment is placed into service, whichever is later.

C. Manufacturer of equipment shall be in compliance with a quality assurance program that meets intent of ASQC Standard C1-1968; General Requirements for a Quality Assurance Program. Compliance shall promote thoroughly tested equipment that will render long service life. Manufacturer shall focus prime concern on necessary formal assurance requirements to ensure equipment failure cannot be attributable to actions or lack of actions.

1.03 SUBMITTALS

A. Make all arrangements with equipment supplier to perform functional factory demonstration and acceptance tests on all equipment supplied. Notify Engineer at least fourteen (14) days in advance of all tests so that Engineer may, at his option, be present for required tests.

B. Monitor manufacturer to assure that approved Quality Assurance Program is closely adhered to and that equipment is manufactured in accordance with specifications and approved submittals.

C. Submit manufacturer data sheets and other descriptive information sufficient to determine compliance with this Specification to the Engineer for approval prior to ordering equipment.

D. Within one week after completing each test, submit two copies each of complete test results to the Engineer.

E. Submit The following drawings to the Engineer for approval:

1. Functional layout of entire network and detailed layouts of each terminal board.
2. Layouts for each location.
3. Cross-connect details for each location.
4. Cabling for each location.
5. Details of interconnections to other equipment.
6. Network management system detail.

PART 2 - PRODUCTS

2.01 GENERAL

A. Provide the Authority with telephone instruments and ancillary equipment as required. Responsibility for system operation shall rest with the Contractor.

B. The Contractor shall have furnished systems of equal size, scope and complexity.

C. The network shall consist of equipment listed herein and as shown on Contract Drawings. Include special cables and miscellaneous equipment necessary to provide fully operational telephone system.

D. Components shall be UL listed.

2.02 ANALOG TELEPHONES

Analog telephones shall, at a minimum, conform to the following:

A. Single line desk telephones without display shall be beige type 2500 (Cortelco or approved equal).
B. Single line wall telephones without display shall be beige type 2554 (Cortelco or approved equal).
C. Single line desk telephones with display screen and two-way speaker shall be Lucent Technologies model 960 or approved equal. Include batteries if required.
D. Two line desk telephones with two-way speaker shall be Lucent Technologies model 922 or approved equal. Include batteries if required.
E. Four line desk telephones with display and two-way speaker shall be Lucent Technologies model 954 or approved equal. Include batteries if required.
F. Comply with Parts 15 and 68 of the FCC rules.
G. Units shall be hearing aid compatible, or have an amplification device for use by hearing impaired persons.
H. Units shall have modular line and handset cords.
I. Number card shall have telephone number typed upon it
J. Units shall employ touch tone (DTMF) dialing.
K. Message waiting light.

2.03 NETWORK TERMINATING UNITS

A. The Contractor shall provide wall mounted Network Terminating Equipment (NT1's) with bulk power supply (with battery back-up) to allow T-interface telephone or data instruments to function with the Verizon AT&T 5ESS switch basic rate U-interface. Unit shall be sized for 100% spare circuits. This equipment shall conform to the CCITT 2B1Q telephone line signaling protocol. Unit shall be Lucent Technologies Powerack 300 Premise Powering Unit or approved equal.

2.04 WAYSIDE TELEPHONES

A. Provide two-line telephones, suitable for use in transit tunnel environments, with an emergency auto-dial (stored Number) function.

B. Provide dual tone modulated frequency (DTMF) telephone with metallic keypad and line terminating impedance of 600 ohms, mounted in an approved weatherproof enclosure equipped with a lockable spring-return door. The heavy-duty aluminum metallic 14 gauge enclosure shall meet the requirements for a no smoke/no halogen tunnel environment. Provide a 24 VDC LEDtronics, Inc. 8000K Cool white SIC/GaN LED, Part # B606-OCW-24N Bayonet Based Lamp or equivalent to be utilized for the Keypad Light within each telephone enclosure. A magnetic contact shall provide power to the LED when the enclosure door is opened.

C. Provide telephones equipped with handset containing a noise-canceling microphone, pressbar "on/off hook" function and six foot Hytrel handset cord.

D. Provide telephones with permanent engraving of "Emergency" on the telephone box that shall meet OSHA 1910.144 Safety Color Code.

E. Provide wayside telephones equipped with a twelve-pair protected terminal block to protect equipment and user from hazardous voltage (lightning, traction power, etc.) which may be induced on the line.

F. Provide a new 12-pair No. 19 AWG cable installed to each twelve-pair block from the Communication Room distribution frames. This cable shall deliver the CENTREX dial tones and 24 VDC Power to each wayside telephone.

G. Wayside telephones shall be mounted on a 4" diameter galvanized steel mast with split base or surface mounted within MBTA approved niches.

H. Provide a blue 24 VDC LED Vandal Resistant Blue Marker Light, part number LEDTronics, Inc. 25mm Edison Screw Based blue Lamp (8 tier Beacon), part # BBL508-05-01 or equivalent with a stone guard mounted on steel mast above the phone box for each wayside telephone. Power for the indicator and keypad 24 VDC LED's shall be from a power supply mounted within the communication rooms.

2.05 PUBLIC TELEPHONES AND ACCESSIBLE TELEPHONE DEVICES FOR THE DEAF

A. Accessible telephone devices for the deaf shall be accessible to people who use wheel chairs, have hearing impairments, and shall conform to the following:

1. ADA 4.31

2. MAAB 37, unless otherwise specified.

3. Unobstructed access shall be a clear space of 30 inches in height, and a clear space of 48 inches wide in front of the telephone.

4. Handset, dial and coin slot shall be mounted less than 54 inches from the floor.

5. The accessible phone shall be equipped with an adjustable volume control for the headset and instructions for its use. The receiver shall be equipped with an inductive coil and identification of its presence.

6. Controls for the accessible phones shall be large pushbutton type.

7. Cord length shall be at least 29 inches long.

8. Vandal proof.

B. Enclosures shall be 16 gauge stainless steel with No. 4 satin finish on all exposed surfaces.

1. Enclosures shall be manufactured by the following:

a. PBG Philips & Brooks/Gladwin, Inc.

i. Standard telephone enclosure: Model number PB 200AWD-SS.

ii. TTD telephone enclosure: Model number PB-200ABRD-SS with TDD

b. ASI American Specialties, Inc.

i. Standard telephone enclosure: Model number Tellete 1452.

ii. TDD telephone enclosure: Model number 1453 with TDD cabinet.

c. Redi Ref-Pressed & Welded, Inc.

i. Standard telephone enclosure: Model number BP1400/ABP3400.

ii. TDD telephone enclosure: Model number BP1460/ABP3460.

d. Or approved equal.

PART 3 - EXECUTION

3.01 INSTALLATION

A. The Contractor shall provide station reviews to determine the appropriate telephones are installed. The station review shall also include the primary and secondary line appearances and the terminal configurations.

B. Furnish and install all material and equipment to form a complete and operational telephone system as specified within these documents and shown on Contract Drawings, in accordance with all manufacturer's instructions, and in compliance with National Electric Code standards, EIA/TIA standards, and all applicable Commonwealth of Massachusetts local codes and ordinances.

C. Affix permanent tags at both ends of connectorized cables designating cable function, piece of equipment connected to, and receptacle designation.

D. Install all wiring in rigid steel conduit where required.

E. Identify all conductors by color code and listing its function.

F. The Contractor shall coordinate, schedule, and obtain all required system connection and testing with M.B.T.A. Communication Department.

G. The Contractor must complete identification of all devices before final inspection and acceptance.

H. The Contractor is responsible for all vendor coordination to ensure that proper service is provided.

3.02 SYSTEM CONFIGURATION AND ACCEPTANCE

Prior to system acceptance, furnish a complete set of as-built drawings and documentation to include the following:

A. Line drawings of all installed equipment in AutoCAD format,
B. Step-by step installation checklist specifying cabling runs and applicable installation tests,
C. System interconnection instructions,
D. Equipment provisioning for each site,
E. Acceptance test procedures,
F. Documentation and acceptance test procedures for network management system.

3.03 FIELD TESTING

A. Furnish all test equipment required and perform all necessary tests to ensure all components of the telephone system are functioning properly in accordance with the intent of this Specification.

B. Each device shall be tested in the presence of the Contractor and MBTA Telecommunication Department. Upon completion of the test, a certified test report shall be submitted for approval.

C. Any system deficiencies observed under testing shall be noted in the certified test report. All deficiencies shall be corrected and system shall be retested. A subsequent certified test report shall be submitted.

D. Test complete system with the Authority as required. If any deficiencies are observed, correct same as described herein. Contractor shall submit as-built drawings and maintenance manuals and spare parts one

week prior to final scheduled testing by the Authority.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16717

FIBER OPTIC COMMUNICATION SYSTEM

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing, installing, testing and placing in operation a Fiber Optic Communication System (FOCS). All equipment, hardware, and ancillary devices required, as described or implied herein and as shown on Contract Drawings, shall be the responsibility of the Contractor.

B. The FOCS architecture shall be based upon a SONET design.

C. The FOCS shall utilize a Pulse Coded Modulation (PCM) System for voice frequency (VF) and data transmission capabilities via a T1 network as shown on the Contract Drawings.

D. Equipment furnished under this section shall conform to following standards:

1. North American Digital Hierarchy
2. Bell USITA TA34
3. EIA / TIA
4. Telcordia
5. Object Management Group
6. IEEE
7. NEC

1.02 QUALITY ASSURANCE

A. Submit proposed manufacturer of FOCS, PCM, and ancillary equipment to Engineer for approval. All equipment shall be new and unused. Past performance and experience shall be factored in evaluating each proposed manufacturer, in part. Additional evaluation criteria will include:

1. Quality and capability of equipment;
2. Manufacturer support;
3. Technology used, system flexibility, and features;
4. Ability to furnish and install within required time frame.

B. Manufacturer shall provide a one-year warranty on all equipment furnished and installed. Contractor shall maintain this warranty, extending to system acceptance or one year after equipment is placed into service, whichever is later.

C. Manufacturer of equipment shall be in compliance with a quality assurance program that meets intent of ASQC Standard C1-1968; General Requirements for a Quality Assurance Program. Compliance shall promote thoroughly tested equipment that will render long service life. Manufacturer shall focus prime concern on necessary formal assurance requirements to ensure equipment failure cannot be attributable to actions or lack of actions.

1.03 SUBMITTALS

A. Make all arrangements with equipment supplier to perform functional factory demonstration and acceptance tests on all equipment supplied. Notify Engineer at least fourteen (14) days in advance of all tests so that Engineer may, at his option, be present for required tests.

B. Monitor manufacturer to assure that approved Quality Assurance Program is closely adhered to and that equipment is manufactured in accordance with specifications and approved submittals.

C. Submit manufacturer data sheets and other descriptive information sufficient to determine compliance with this Specification to the Engineer for approval prior to ordering equipment.

D. Within one week after completing each test, submit two copies each of complete test results to the Engineer.

E. Submit optical loss calculations for each span of PCM communication system to the Engineer for approval, including total anticipated loss in dB between locations and gain margin in dB above level required for BER (Bit Error Rate) performance as specified by manufacturer.

F. Submit complete heat dissipation calculations to the Engineer for approval for the following:

1. Equipment to be installed within cabinets,
2. Heat generated by each piece of equipment within each cabinet,
3. Total heat generated within each cabinet,
4. Maximum ambient temperature allowed without exceeding manufacturer ratings for equipment,
5. Graph of heat dissipated versus temperature difference, where temperature difference equals temperature inside cabinet minus ambient temperature.

G. Submit the following drawings to the Engineer for approval:

1. Functional layout of entire network and detailed layouts of each terminal board,
2. Layouts for each location,
3. Cross-connect details for each location,
4. Cabling for each location,
5. Details of interconnections to other equipment,
6. Network management system detail.

H. The Contractor shall submit to the Engineer data sheets and drawings for a PCM equipment rack with roll out rack assembly for rear rack accessibility prior to procuring or fabricating such equipment.

PART 2 - PRODUCTS

2.01 GENERAL

A. Provide the Authority with FOCS, PCM, and ancillary equipment as required. Responsibility for system operation shall rest with the Contractor.

B. Contractor shall have furnished systems of equal size, scope and complexity.

C. The network shall consist of equipment listed herein and as shown on Contract Drawings. Include special cables and miscellaneous equipment necessary to provide fully operational telephone system.

D. Components shall be UL listed.

2.02 CHANNEL BANK

A. Furnish and install "enhanced" D4 type PCM channel banks at locations shown on Contract Drawings, which are fully compatible with Standard North American Digital Hierarchy format signal at DS-1 level.

B. Furnish channel banks consisting of two independent digroups within a single chassis. Channel bank digroups shall multiplex up to twenty-four voice frequency or data channels into a single DS-1 bit stream. If Contractor intends to utilize channel banks with a single digroup (24 channels) per chassis, then two single digroup channel banks shall be required for each channel bank shown on Contract Drawings.

C. Furnish channel banks with amounts and types of channel unit interface cards as shown on Contract Drawings. Channel unit interface cards, as specified below, shall be interchangeable between channel banks.

D. Furnish channel with internal stabilized clock source, with capability to operate in three modes:

1. Free-Run-Mode: Clock source operates independently, as a Master Source capability to output a composite clock signal when operated in this mode.

2. Synchronized Mode: Clock source is slaved to a composite clock (DDS) signal provided from an external source, with capability to output a separate signal (synchronized to incoming clock). If incoming clock signal is interrupted, channel bank shall synchronize to internal source.

3. Generate Mode: Clock source is synchronized via a clock signal derived from framing bits in incoming DS-1 bit stream. If incoming DS-1 bit stream synchronization is lost, channel bank shall synchronize to internal source.

E. Furnish channel banks suitable for mounting on EIA equipment rack and that meet or exceed the following requirements:

1. Voltage: -48 VDC
2. Current: 1.0 Amp (fully equipped)
3. Temperature: 15°C to 45°C
4. Humidity: 90% at 35°C

F. Furnish channel banks with LED indicators for power and local and remote alarms located on front panel of channel bank. Furnish channel banks equipped with Form C relays that close when an alarm condition is

detected. Form C contacts shall be utilized to interface to communications PLC equipment as necessary.

2.03 CHANNEL UNIT INTERFACE CARDS

A. Furnish and install types of voice frequency and data interface cards as shown in Contract Drawings.

B. Furnish cards with 600 ohm interface for an analog VF circuit. Furnish card type capable of permanent labeling on front panel of card. Furnish cards with test access for Tip, Ring, Tip 1 and Ring 1 connections available on front panel of circuit card. Furnish cards with direct test access via bantam jacks located on front panel of card, or via a multi-pin patch cord leading to a VF patch panel equipped with 310 or bantam jacks. Furnish cards with a handle for inserting and removing card located on front panel. Furnish cards that lock into place when fully inserted into edge connector socket.

C. Furnish and install internal hybrid to interface two-wire cards to line so that all internal signal processing is similar to that for four-wire cards. Furnish internal hybrid with selectable network build-out capacitance of 0 to 0.126 uF in 0.002 uF increments. Install two-wire and four-wire cards to be transformer isolated from circuit, with capacitive coupling so DC talk-battery can be applied to circuit on instrument side.

D. On transmit side, adjust incoming VF signal level to Transmission Level Point (TLP), sampled at a frequency of 8 KHz, and converted to 8 bit PCM words to make up a 64 Kb/s signal. On receive side, decode, filter and adjust recovered incoming 8 bit PCM words to appropriate TLP.

E. Perform time slot selection by setting dip switches on voice frequency interface card. Install switches to be inaccessible from front of card.

F. Furnish and install two-wire E&M cards that meet or exceed the following requirements:

1. Impedance:	600 ohms
2. Transmit (Input) Level:	0 to -12.7, adjustable
3. Receive (output) Level:	+5.7 to -7.7, adjustable
4. Loss Stability (end-to-end):	+/- 0.5 dB
5. Idle Channel Noise	23 dBrnc max.
6. Signal Distortion	
i) 0 to -30 dBmO Input	33 dB
ii) -40 dBmO Input	27 dB
iii) -45 dBmO Input	22 dB
7. Trans-hybrid Loss	34 dB (echo)
8. Frequency Response:	
i) 200 Hz	0 to -5 dB
ii) 300 to 3000 Hz	+0.5 to -1.0 dB
iii) 3200 Hz	+0.5 to -1.5 dB
iv) 3400 Hz	0 to -3.0 dB
9. Delay Distortion:	94 PAR min.

10. Operating Temperature: 50°C

G. Furnish and install four-wire TO cards that meet or exceed following requirements:

1. Impedance: 600 ohms

2. Transmit (Input) Level: -17.5 to 8 dBm

3. Receive (Output) Level: -17.5 to 8 dBm

4. Loss Stability: +/- 0.5 dB (end-to-end)

5. Idle Channel Noise; 23 dBrnc0

6. Signal Distortion:
   i) 0 to -30 dBmO Input: 33 dB, min
   ii) -40 dBmO Input: 27 dB, min
   iii) -45 dBmO Input: 22 dB, min

7. Return Loss:
   i) 1000 Hz 28 dB, min
   ii) 300 to 3000 Hz 23 dB, min

8. Frequency Response:
   i) 200 Hz +.25 to -3.0 dB
   ii) 300 to 3000 Hz -.3 to + 0.3 db
   iii) 3200 Hz +.3 to -1.5 dB
   iv) 3400 Hz +.25 to -3 dB
   v) 4000 Hz <14 dB

9. Operating Temperature 50°C

H. Furnish and install 3660-03 2W Ringdown 600 channel units and Foreign Exchange Subscriber (FXS) Cards that are configurable for loop-start or ground-start signaling on PBX or Telco circuits. Furnish and install 3660-03 2W Ringdown 600 channel units at office (PBX or Telco line) end of circuit and FXS cards at instrument end of circuit.

I. Furnish and install 3660-03 2W Ringdown 600 channel units that detect office signaling data, where applied to Tip and Ring leads. This data shall be encoded and added into outgoing bit stream and sent to remote FXS card. Signaling data from remote FXS card shall be removed from incoming bit stream, decoded and interpreted to apply signaling to Tip and Ring leads to office.

J. Furnish and install FXS cards to detect status of Tip and Ring Leads from subscriber instrument. This data shall be encoded and added into outgoing bit stream. Signaling data from remote 3660-03 2W Ringdown 600 channel unit shall be decoded and interpreted to apply ringing voltage to Tip and Ring leads to subscriber instrument.

K. Furnish and install 3660-03 2W Ringdown 600 channel unit and FXS cards that meet or exceed the following requirements:

1.	Impedance:	600 Ohms
2.	Transmit (FXS):	-17.4 to 2.8 dBm, adjustable
3.	Receive Level (FXS):	-21.4 to 0.8 dBm, adjustable
4.	Transmit Level (Channel Unit):	-4.5 to 1.8 dBm, adjustable
5.	Receive Level (Channel Unit):	6.3 to 0 dBm
6.	Idle Channel Noise:	<20 dBrnc0
7.	Signal Distortion	
	i. 0 to -30 dBmO Input:	33 dB min.
	ii. -40 dBmO Input:	27 dB min.
	iii. -45 dBmO Input:	22 dB min.
8.	Echo Return Loss:	28 dB min.
9.	Singling Return Loss:	20 dB min.
10.	Frequency Response:	
	i) 200 Hz :	-3 dB to 0.25 dB
	ii) 300 to 3000 Hz:	-0.75 dB to +0.25 dB
	iii) 3200 Hz:	-0.75 dB to +0.25 dB
	iv) 3400 Hz:	-1.5 dB to +0.25 dB
	v) 4000 Hz:	<14 dB
11.	Loop Length	0 to 1,300 ohms
12.	Longitudinal Balance	
	i) 200 Hz :	58 dB min.
	ii) 1000 Hz:	58 dB min.
	iii) 3000 Hz:	53 dB min.
13.	Crosstalk:	>65 dB, 200 to 3,400 Hz
14.	Operating Temperature:	50°C

L. Furnish and install Multi-rate Office Channel Unit Data Port Channel Units (OCU) that meet or exceed the following requirements. The OCP allows direct digital access to a T-Carrier time slot. The OCU channel units are utilized for digital data system or basic digital service.

1. The channel unit shall comply with UL standard 1459 Second Edition.

2. 2.4 kb/s, 4.8 kb/s, 9.6 kb/s, 19.2 kb/s, 38.4 kb/s, 56 kb/s, 64 kb/s and switched 56 kb/s (Sw 56 kb/s) operation.

3. Secondary channel up to 56 kb/s.

4. Extended loop range at all rates.

5. DS0 access: Bantam Jacks.

6. Latching (up to 64 kb/s) and normal loopbacks (up to 56 kb/s).

M. The Contractor shall provide one set of Customer Service Units / Digital Service Units (CSU/DSU) per OCP channel. The CSU/DSU provides a high-speed data connection that shall support both synchronous and asynchronous data communications. The CSU/DSU shall meet or exceed the following requirements:

1. Front panel mounted controls and display screen.

2. "AT" Commands or V.25 bis commands in-band.

3. Ability to configure remote units from local unit via the front panel, AT commands, or V.25 bis commands.

4. The Contractor shall provide a DTE cable for each CSU/DSU.

N. Furnish ten percent (10%) spare voice frequency interface cards beyond those specifically required for installation in each channel bank. Furnish two spare circuit cards for each type of channel bank common equipment card. Spare cards are to be delivered at a location designated by Engineer.

2.04 TERMINAL BLOCKS

A. Station Main Distribution Frame.

1. The Contractor shall provide wall mounted terminal blocks located at the main distribution frame (MDF) in the communications room.

2. The terminal blocks shall be Krone type 50 pair blocks with hinged orange covers and 89D standoff bracket.

3. Provide separate terminal blocks for TR, T1R1, E Lead, and M Lead.

B. 45 High Street Main Distribution Frame

1. The Contractor shall provide 200 pair rack mount Krone type terminal blocks, identical to those existing at 45 High Street. Include number tags, six Krone type block termination tools, 12 Krone type block winged adapters, and all ancillary equipment to provide a neat workman like installation.

2. Provide separate terminal blocks for TR, T1R1, E, and M leads. The M.B.T.A. Communications Department shall determine location of blocks prior to installation.

3. The Contractor shall update the Operations Control Center wiring lists and drawings (both hardcopy and electronic file).

2.05 POWER REQUIREMENTS

A. General Requirements

The Contractor shall furnish and install -48 VDC power supplies at the location where fiber optic communications electronics are installed. Each power supply shall consist of a 110 VAC to -48 VDC battery charger, a -48 V battery bank and power distribution panel(s). The battery chargers shall be sized to provide a minimum of 150% of the maximum current draw of the fiber optic multiplexer, channel bank(s), ring generator, and alarm equipment installed at that location. The batteries at each location shall be sized to provide 100% of the maximum current draw of the local communications system equipment for a period of eight (8) hours. The charger and the battery bank are to be mounted in a 19" equipment rack.

B. Battery Charger

The Battery chargers furnished shall be regulated, 110 VAC to 48 VDC (nominal), single phase float/equalize chargers. Each charger shall be equipped with analog voltage and current output meters, accurate to within 2%, mounted on the front panel. The float and equalize voltages shall be adjustable. A 24 hour equalizer timer shall be located on the front panel of the charger.

Each battery charger shall be equipped with alarm output relay contacts to indicate loss of power. Each battery charger shall meet or exceed the following requirements:

1.	DC Voltage	-	48-60 Volts, adjustable
2.	Regulation	-	+- 1/2% steady state
3.	Filtering	-	< = 22 dBrnC
4.	Ripple Voltage	-	< = 30 mV RMS
5.	Noise	-	Inaudible (< = 40 dB)
6.	Temperature	-	O°C to +50°C (Operational)
			-40°C to +85°C (Storage)
7.	Humidity	-	0 to 95%

C. Batteries

The battery banks supplied shall consist of connected groups of 2.0 volt sealed, non-venting, maintenance free, lead-acid cells. Each cell shall meet or exceed the following requirements:

1.	Temperature	-	-65°C to +65°C (Storage)
		-	-65° to +65°C (Discharge)
		-	-40°C to 65°C (Charge
2.	Storage Time	-	7200 days @ 0°C
		-	1200 days @ 23°C
		-	60 days @ 65°C
3.	Cycle Life	-	200 cycles, 100% discharge
4.	Float Life	-	8 years @ 23°C

D. Power Distribution Panel

Each equipment rack shall be equipped with a power distribution panel as shown on the Contract Drawings. Each panel shall have a minimum of eight separately fused power output positions. The fuse current ratings shall be per manufacturer instructions. The fuses shall be LED indication type.

G. At 45 High Street the Contractor shall connect to the existing –48 VDC power grid located on the second floor. The Contractor shall supply all circuit breakers, wiring, conduit, etc. for the installation.

2.06 SYNCHRONOUS OPTICAL NETWORK (SONET)

A. The Contractor shall provide a complete Synchronous Optical Network (SONET). All equipment installed shall be fully SONET compliant. System shall allow for optical interconnect allowing mid-span meet, intra-office mixed vendor interconnects, overhead channels for OAM&P functions, and synchronous networking.

B. The SONET equipment shall be an add/drop multiplexer that offers aggregation and high-bandwidth transport of voice and data communications on a single platform.

C. The SONET equipment shall support DS-1, DS-3, OC-12, OC-48, and 10/100 Ethernet speeds. In addition, the SONET equipment shall employ the following network configurations:

1. Terminal mode,
2. Linear add/drop multiplexer.
3. Unidirectional path-switched ring,
4. Subtending rings,
5. Path protected mesh network.

D. The SONET equipment shall have a minimum of eight card slots. The slots shall be assigned to high speed (optical and Ethernet), common control, and equipment interface. All slots shall be card ready so as when a card is installed the SONET equipment recognizes and automatically boots-up. The SONET equipment shall have redundant power supplies. The SONET equipment shall have LEDs for critical, major, minor, and remote alarms. Insertion or removal of cards shall not require powering down SONET equipment.

E. The node name, configuration database, IP address, and system software shall be stored in non-volatile memory. The SONET equipment shall allow system software upgrades while the equipment is in service and not affect data traffic.

F. The SONET equipment shall provide a minimum of 28 DS-1 circuits and a minimum of 3 DS-3 circuits.

G. The optical cards shall provide intermediate or short range, Telcordia compliant, GR-253 SONET OC-12 interfaces. The interface shall operate at 622.08 Mbps over a single-mode fiber optic span. The interface shall support VT payloads and non-concatenated or concatenated payloads of STS-1, STS-3c, STS-6c, or STS-12C. If required, optical cards shall provide an intermediate range, Telcordia compliant, GR-253 SONET OC-48 interface. The interface operates at 2488.320 Mbps over a single-mode fiber optic span. The interface shall support VT payloads and non-concatenated or concatenated payloads of STS-1, STS-3c, STS-6c, or STS-12C.

H. The Ethernet cards shall have a minimum of four IEEE 802.3 compliant, switched 10/100 base-T ports. Ports shall independently detect the speed of an attached device (auto-sensing) and automatically connect at the appropriate speed. The ports shall auto-configure to operate at either half or full duplex and can determine whether to enable or disable flow control.

I. The SONET equipment shall provide redundant electrical protection for DS-1 circuits and redundant optical protection for fiber optic circuits.

J. The system software shall provide for the operation, administration, maintenance, and provisioning functions. These shall include provisioning cards, rings, and circuits; creating protection groups; setting timing parameters, viewing and clearing alarms; provisioning data communication channels; backing-up and restoring database; and troubleshooting, including creating diagnostic files and performing loopbacks. The software shall include, at a minimum, the following:

1. Network Window – shall provide information about the SONET network and allow network management. The Contractor shall be responsible for updating all network maps to accurately illustrate nodes. Colored node icons shall represent node status.
2. Node Window – shall provide information regarding the node and display a graphic representation of the card shelf. Colored card and port icons shall represent card and icon status.
3. Card Window – shall provide information regarding individual cards and display a graphic representation of the selected card. This window shall allow card specific maintenance tasks.
4. The software shall support Common Object Request Broker Architecture (CORBA) as a management protocol.
5. The software shall display SONET line performance monitoring for OC-N, DS-1, and DS-3 statistics, as defined in GR-253-CORE and GR-820-CORE.

K. The SONET equipment shall be provided with a minimum of six external alarm inputs and two external alarm controls. The external alarm controls shall be connected to the communication PLC for remote alarm notification. The external alarm controls shall be user definable external input alarms, remote alarms, or severity based alarms.

L. All cards and connections shall be located on the front of the SONET equipment. The Contractor is responsible for providing all cabling and cable support hardware for a complete installation. The Contractor shall ensure that fiber optic cables are routed properly and that minimum bend radii are not exceeded.

M. The Contractor shall provide ten percent spare cards for each SONET node installed.

N. The SONET equipment shall, at a minimum, conform to the following specifications:

1. Approximate Dimensions (H x W x D) in inches: 5 x 19 x 11
2. Approximate Weight: 30 pounds
3. Terminal Access: RJ-45
4. Database Storage: Non-volatile 96 MB, FLASH memory
5. BITS Interface: 2 DS-1 BITS inputs, 2 derived DS-1 Outputs
6. System Timing:
   a. Internal Stratum 3 per Telcordia GR-253-GORE
   b. Free Running Accuracy: 4.6 ppm
   c. Holdover Stability: 3.7 x 10 –7/day, including temperature (>255 slips in first 24 hours).
   d. Reference: External BITS, line, internal
7. TL1 Craft Interface: 9600 baud, RS-232 DB9 connector
8. External LAN Interface: 10 Base-T Ethernet
9. Alarm Interface: visual and audio for critical, major, minor, remote
10. Alarm Contacts: 0.045 mm, -48V, 50 mA
11. Operating Temperature: 0 to +55°C
12. Operating Humidity: 5 – 95% non-condensing

13. Input Power: -48V DC, required –42 to –57 V DC
14. Power Consumption (approx.): 300 watts
15. Network Configurations:
    a. Terminal mode,
    b. Add-drop multiplexer mode,
    c. Regenerator mode,
    d. Two-Fiber Unidirectional Path Switched Ring (UPSR)
    e. Path Protected Mesh Ring (PPMN)

PART 3 - EXECUTION

3.01 INSTALLATION

A. The Contractor shall provide circuit reviews to determine that the appropriate channel cards are installed.

B. Furnish and install all material and equipment to form a complete and operational SONET system as specified within these documents and shown on Contract Drawings, in accordance with all manufacturer's instructions, and in compliance with standards as listed in Section 1.01D and all applicable Commonwealth of Massachusetts local codes and ordinances.

C. Affix permanent tags at both ends of cables designating cable function, piece of equipment connected to, and receptacle designation.

D. Install all wiring in rigid steel conduit where required.

E. Identify all conductors and fiber optic strands by color code and listing its function.

F. The Contractor shall coordinate, schedule, and obtain all required system connection and testing with M.B.T.A. Tele-communication Department.

G. The Contractor must complete identification of all devices before final inspection and acceptance.

H. The Contractor shall power all equipment from the communication battery bank install per paragraph 2.05 of this Specification.

3.02 SYSTEM CONFIGURATION AND ACCEPTANCE

Prior to system acceptance, furnish a complete set of as-built drawings and documentation to include the following:

A. Line drawings of all installed equipment in AutoCAD format.
B. Step-by step installation checklist specifying cabling runs and applicable installation tests.
C. System interconnection instructions.
D. Equipment provisioning for each site.
E. Acceptance test procedures.
F. Documentation and acceptance test procedures for network management system.

3.03 FIELD TESTING

A. Furnish all test equipment required and perform all necessary tests to ensure all components of the SONET system are functioning properly in accordance with the intent of this Specification.

B. Each device shall be tested in the presence of the Contractor and Telecommunications Department. Upon completion of the test, a certified test report shall be submitted for approval.

C. Any system deficiencies observed under testing shall be noted in the initial certified test report. All deficiencies shall be corrected and system shall be retested. A subsequent certified test report shall be submitted.

D. Test complete system with the Authority as required. If any deficiencies are observed, correct same as described herein. Contractor shall submit as-built drawings, maintenance manuals and spare parts one week prior to final scheduled testing by the Authority.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16725

CLOSED CIRCUIT TELEVISION SYSTEM

PART 1 - GENERAL

1.01 DESCRIPTION

A. It is the intent of this section to furnish, install and test a Closed Circuit Television System (CCTV). The System shall be a real time video system.

This location will be a primary node as defined in the Blue Line Fiberoptic network and will operate in the same manner as the Revere Beach, Suffolk Downs and Wood Island Stations.

The video path between the new Maverick Station and 45 High Street will be via the existing MBTA fiber plant.

B. The path from 45 High Street to Police Headquarters will be via the MBTA Matrix Switching system and its associated Fiberoptic System.

C. The equipment must be compatible with the CCTV System installed at 45 High Street and the Police Station.

D. The system described herein is required to provide monitoring facilities for supervisory personal at 45 High Street and M.B.T.A. Police Department. Both monitoring facilities shall control the existing VICON switcher located at 45 High Street, through their existing interfaces. The Contractor shall provide any modifications to the existing software at 45 High Street.

E. The new Maverick Station video signals will be connected to a new Multiplexer/ Switcher and recorder for recording of new Maverick Station cameras at 45 High Street and to the Matrix Switcher System. This conforms to the BLUE Line standard operating system.

F. CCTV cameras and camera housings shall be powered from Communications Room. Exact locations of cameras to be determined by the Contractor and approved by the Authority. All electrical tests performed to demonstrate compliance with this specification shall be referred to standard test procedures or shall be described in full by the manufacture to the Engineer for his acceptance and approval. The equipment to be supplied shall be capable of operating within specification when subjected to temperature, humidity, vibration and light conditions encountered at the location.

G. The major components of the CCTV System shall include, but not limited to the following equipment.

1. CCTV cameras with fixed mountings and fixed focus lenses
2. Modulators to convert the analog video signal for transmission via the Fiberoptic cable plant.
3. Demodulators for converting the signal back to baseband video
4. Fiberoptic transmitters and receivers to connect to the fiber plant
5. Multiplexer/ Switcher for recording the camera signals
6. Video tape recorder
7. Camera enclosures, mounting hardware, coaxial cable power cable, conduit, connectors, and any other miscellaneous hardware.
8. All cameras shall be suitable for outdoor application.

1.02 QUALITY OF MATERIAL

A. All material shall be new and unused and the workmanship shall be in accordance with the highest standards of the electronic equipment industry. Bids will be accepted only for new and current equipment. Equipment discontinued by the manufacturer will not be accepted. All components shall be UL Listed.

B. Equipment purchased under this specification shall be covered by standard E.I.A. and the manufacturer's warranties against material and workmanship commencing from the date the authority accepts the CCTV System for the period noted on the manufacturer's warranty or for a minimum of three (3) year, whichever is greater.

1.03 SUBMITTALS

A. Prior to ordering any of the equipment required under this section, the Contractor shall submit six (6) copies of the following to the Engineer for approval:

1. Full technical data and manufacturer cut sheets for all of the equipment proposed under this section.

2. Site specific plans showing details of the following:

   a. Camera enclosure location and mounting
   b Cable and conduit
   c. Light intensity ranges throughout the surveillance areas (determined by actual field tests)

3. A complete wiring diagram showing all equipment for the CCTV system.

B. Prior to installing any equipment, the Contractor shall submit to the engineer six (6) copies of a detailed test procedure, intended to insure that all parts of this system are functioning properly, in accordance with this Specification and Contract Drawings. The tests performed shall include but not limited to the tests outlined in Paragraph 3.02 of this section. The detailed test procedure shall include a description of all test equipment to be used, and specific pass/fail criteria for each test.

PART 2 - PRODUCTS

2.01 CCTV CAMERA

A. The Cameras furnished under this section shall have the following minimum specifications:

1. The image device shall be a 1/3" interline transfer CCD (768 x 494 pixels)
2. The scanning shall be 525 lines/60 fields/30 frames
3. The Horizontal resolution shall be 480 lines
4. The video output shall be 1.0 V p-p NTSC composite, 75 ohms/ BNC connector
5. The signal to noise ratio shall be 50 dB (min) (AGC OFF, weight ON, sharp)
6. The camera shall have selectable aperture correction H and V
7. The camera shall have Electronic Light Control
8. Minimum Scene Illumination 0.09 fc (.9 lux) at F0.75, 0.20 fc (2.0 lux) at F1.2
9. The camera shall have ATW/AWC selectable with Fine adjustment

10. The camera shall have Adaptive Backlight Compensation
11. The camera shall accept C or CS mount lenses
12. The camera shall accept DC or Video ALC Lenses
13. The camera shall have selective AGC
14. The camera shall operate with an ambient temperature of 14° F to 122° F
15. The camera power shall be 120 VAC

2.02 FIBEROPTIC TRANSMISSION

A. Video Multiplexer/ Demultiplexer

1. The Video Multiplexer/ Demultiplexer Equipment allows transmission and reception of NTSC video signals over distances up to 24 miles. The VMx and VDx shall be capable of supporting dual video transmitters and video receivers for redundant optical operation with automatic switch-over.

2. The VDx and VMx mount in a 19 inch EIA rack. The maximum height for a 24 channel system shall not exceed 11 inches.

3. The VDx and VMx shall have local alarms that indicate primary power failure, and have the built-in capability to communicate these alarms and the alarms from the Video Transmitter(s), Video Receiver(s), Video Modulator/ Demodulator(s).

4. The Video Modulator shall be rated from minus 10 to plus 50 degrees Celsius for operation. It shall convert any NTSC baseband signal to a Frequency Modulated (FM) signal; accept the baseband signal through nickel plated, gold flash contact, bulkhead female BNC connectors. It shall accept a composite video signals at 1.0 V +/- 3 dB p-p and operate with an input of 1.0 V +/- 6 dB and have an input impedance of 75 ohms and a return loss of 30 dB in compliance with EIA RS-250C.

5. The Video Demodulator shall be rated from minus 10 to plus 50 degrees Celsius for operation. It shall convert the Frequency Modulated (FM) signal to a NTSC baseband video signal through nickel plated, gold flash contact, bulkhead female BNC connectors.

B. Video Transmitter

1. The Video Transmitter accepts the FM signal from the Video modulator(s) and converts them to a composite optical signal. The Video Transmitter shall have the optical power required to transmit 16 or more video channels within specification. The unit shall have local alarms for laser over temperature and major circuit failure. The unit shall have ST optical connectors.

C. Video Receiver

1. The Video Receiver shall have an optical dynamic range of at least 18 dB, have local alarms for low optical power, optical power over-drive and for major circuit failure. The unit shall have ST optical connectors.

2.03 DIGITAL MULTIPLEXER

A. The digital video Multiplexer shall provide multiplexed field recording of 16 video inputs. The Multiplexer shall offer a choice of either digital multiscreen display of live video while not recording or sequencing full screen video while recording is taking place. The unit shall provide looping outputs for camera video. It shall provide one alarm input for each video input, plus one auxiliary alarm input. Two alarm outputs shall be provided. Camera selection for alarm recording shall offer three options

1. All cameras normally selected to record shall be recorded during an alarm condition;
2. Only alarmed cameras shall be recorded;
3. Alarmed cameras shall be interleaved with nonalarmed cameras to provide increased frequency of alarmed camera recording.

B. The unit shall provide a user-programmable twelve-character title for each camera and shall record time and date with each video image. The Multiplexer shall feature dual monitor outputs. Playback functions for the main monitor shall include:

1. Full screen,
2. Four quad screens,
3. Eight different picture-in-picture displays, with inset movable to any of the four corners of the screen,
4. Sixteen-way split screen (cameo),
5. Nine-way split,
6. Quad plus cameo split,
7. 2X electronic zoom and pan/tilt functions in full-screen playback mode,
8. Switchable full-screen alarm playback,
9. Sequencing video from multiple cameras for full screen display or any of the multiscreen segments,
10. Still-frame viewing for full screen display or any of the multiscreen segments.

C. The secondary monitor shall display full screen only and shall offer sequencing videos. The Multiplexer shall feature time base correction, eliminating the need for camera synchronization. The unit shall feature a digital activity detector on all channels. Dimensions without feet or rack-mounting brackets shall not exceed: height (H) 3.5 in. (8.9 cm); width (W) 16.7 in. (42.5 cm); depth (D) 17.7 in. (45.0 cm).

2.04 VIDEO CASSETTE RECORDER

A. The recorder shall be installed on the seventh floor of 45 High St. as directed by the Engineer and shall be front loading and accept a 1/2" VHS cassette tape. Recording and Playback speeds shall be selectable: 2,12,24,48,72,120,360,480,600, and 720 hours and include a 1-shot mode. The recorder shall have a seven day programmable timer which starts and stops the recording for any two selectable periods for each day of the week. The resolution shall be 350 lines in black and white or 240 lines in color in all recording speeds. The unit shall be rack mountable with optional rack mount kit. Include thirty (30) blank VHS tapes and lockable storage enclosure. The signal to noise ratio shall be better than 45 dB. The video input shall be 1.0 V p-p, 75 ohms unbalanced. The video output shall be 1.0 V p-p 75 ohms unbalanced. The signal format shall be EIA Standard 525 lines, 60 fields/sec.

2.05 CAMERA ENCLOSURES

A. The Camera Enclosure shall utilize a two piece body, consisting of a top cover and a lower body. The lower body shall be designed having a drop bottom that is hinged at the front, allowing it to be forward opening from the rear, thereby providing maximum access to the interior of the enclosure for service and maintenance. The drop bottom shall latch close utilizing a key lock. Included in the design of this enclosure shall also be a dual purpose camera sled/elevation block, a factory installed 120 VAC thermostatically controlled blower and heater and it shall utilize a printed circuit board for distribution of all power requirements. The Contractor shall affix a weatherproof 1 inch by ¾ inch numerical label in front of each CCTV enclosure. The number shall correspond to the camera's port number in the video multiplexor.

B. The enclosure shall be mounted as approved by the Engineer, using stainless steel brackets and tamper-proof screws. The enclosures shall lock closed and shall allow access to the removal of the camera and other equipment without removing the enclosure from its mounting bracket.

2.06 COAXIAL CABLE

A. The coaxial cable furnished under this Contract for use within the CCTV System shall be 75 ohm with a 95% braided copper shield and a #18 AWG solid copper center conductor. The jacket material shall be polyethylene.

PART 3 - EXECUTION

3.01 INSTALLATION

A. CCTV Cameras

1. The CCTV Cameras shall be installed in the locations and with the orientations shown on the Contract Drawing. The camera housings shall be mounted in accordance with the approved site specific detail plans.

B. Conduit

1. The Contractor shall install all conduit in accordance with the approved Conduit Routing Plan. The Contractor shall install the conduit runs so that the minimum bending radius of the coaxial cable shall not be exceeded at any time.

C. Coaxial Cable

1. The Contractor shall install all coaxial cable in accordance with the manufacture's recommendations for maximum pulling tension and minimum bending radius. The Contractor shall monitor the coaxial cable installation to ensure that the cable is not crimped or kinked during installation. The coaxial cable and 120 VAC power cable shall be installed in separate conduits. Both conduits shall emanate from the communications room. The Contractor shall notify the Engineer at least five (5) working days in advance of installing any coaxial cable so that the engineer or his representative may be present. The ends of each conduit shall be sealed with an Authority approved sealing compound after the CCTV camera power and coaxial cables have been installed.

D. 45 High Street Equipment

1. The Contractor shall install the Dispatcher video CCTV rack within the Communication Equipment Room at 45 High Street in a location approved by the Engineer. The Contractor shall install the Multiplexer, Recorder and Fiberoptic equipment as directed by the Engineer. Rack mounts, panels mounts, AC power and enclosures shall be the responsibility of the Contractor. The Contractor is responsible for all software changes in both the Vicon Industries equipment and the OCC video control software. In addition, the Contractor shall provide five updated, laminated matrix cards illustrating the Maverick cameras and their port assignments in the Vicon matrix.

E. Interface to Fiber Optic Cable

1. The Contractor shall coordinate with the Authority, the installation of new Single mode video equipment utilizing one of the spare fibers in the existing Authority Fiber Optic System for the transmission of the new Maverick Station CCTV video. All modifications shall be made in a manner consistent with the existing wiring practices for Fiber Optic. All modifications to the existing Fiber Optic System shall be made while the system remains in service.

3.02 TESTING

A. Prior to connecting any equipment to coaxial cable segments, the Contractor shall test the cable segment with a Time Domain Reflectometer (TDR) to ensure cable integrity. The Contractor shall include a hard bound test report of the output of the TDR trace for each section of cable.

B. After all installation is complete, the Contractor shall verify proper operation of all control functions and Video channels as described herein. The Contractor shall notify the Engineer at least five (5) days in advance of this test so that the Engineer or his representative may be present.

C. Prior to connecting any equipment to the fiber optics cable strand, the Contractor shall test the strands with a Optical Time Domain Reflectometer (OTDR) to ensure fiber integrity. The Contractor shall include a hard bound test report of the output of the OTDR trace for each spare strand.

3.03 TRAINING

A. Provide 5 mandays of the services of a factory trained service engineer, for assistance in installation, specifically trained on the type of equipment specified. Mandays listed are exclusive of travel time, and do not relieve the Contractor of obligation to provide additional services required to place the equipment in operation. If the equipment and material has not been installed as indicated and as specified, and additional time of the factory-trained service engineer beyond that specified above is warranted to correct the deficiencies, provide this additional time at no additional cost to the Authority.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16741

COMMUNICATION PROGRAMMABLE LOGIC CONTROLLER

PART 1 - GENERAL

1.01 DESCRIPTION

A. The Work specified herein consists of furnishing, testing, and installing a control and monitoring system utilizing a communication programmable logic controller (CPLC) for control and monitoring of the tunnel ventilation system, fire and security alarms, and misc. items at specified locations. Specifically, the work includes development of an automatic monitoring and control system, hereinafter specified or otherwise required for a complete and fully operable system.

B. The full integration of all software and hardware elements into the existing 45 High Street co-processors such that all appropriate 45 High St. Consoles have parallel control and fire, security, and misc. alarm monitoring, shall be the sole responsibility of the Contractor.

C. The Work also includes the following:

1. Working drawings indicating the dimensions, weight, and full mounting details of all components.

2. Furnishing terminal-to-terminal and full inter-connection drawings between components specified.

3. Programming of CPLC and program software documentation as required by the performance specification described herein.

1.02 GENERAL REQUIREMENTS

A. Supervision of the CPLC system installation: The Manufacturer shall provide the services of a qualified technician who is competent and experienced with the work involved in the installation of the CPLC systems of this type. The technician shall, at the site, supervise the CPLC and fan control installation and shall be available when any of the work in connection with the CPLC system installation is proceeding, to verify that the work is properly performed.

B. Equipment outline for installation of Communications Programmable Logic Controllers (CPLC).

1.03 SUBMITTALS

A. Working Drawings:

1. Submit working drawings for each component of the CPLC system, i.e. communication programmable logic controllers, interface panel, etc.

2. Show and fully dimension details of all components of the system including the following:

   a. Communication programmable logic controllers.

   b. Weight of each CPLC and CPLC enclosure.

   c. Bill of material for each CPLC and control panel.

3. Submit technical data including rating, capacity, and manufacturer's type and catalog number for each module of the CPLC and operator workstation.

4. Submit schematic and wiring diagrams complete with terminal numbers.

5. Submit list of terminals with their designation for each I/O module terminal block.

6. Submit procedures for programming and troubleshooting.

7. Submit relay ladder logic diagrams prepared in accordance with the performance criteria.

8. Full interconnect diagram for overall system, i.e. CPLC cabinets, ITC (Interface Terminal Cabinet) and fan control devices (Motor Control Centers (MCC), Fan Vibration Monitoring System, and Fire Personnel Control Panel and security interface), communications, etc.

9. Software Documentation

   a. The Contractor shall provide as-built documentation of all software developed and implemented for the entire control and monitoring system.

      (1) CPLC system diagnostic

      (2) Ladder Logic Diagrams

         a) Address tables for I/O

         b) Internal address information providing a traceable path within ladder logic diagrams, for trouble-shooting or changing ladder logic.

      (3) I/O wiring diagrams

         a) Field wiring diagrams

         b) Field to CPLC wiring diagram

         c) CPLC wiring diagrams

         d) Overall ventilation fan control system wiring diagrams, i.e. CPLC cabinets, ITC (Interface Terminal Cabinets) and fan control

system devices (e.g. Motor Control Centers (MCC), Fan Vibration Monitoring System, and Fire Personnel Control Panels), etc.

B. Factory Tests: Submit at completion of factory testing, including program software, six certified copies of test results.

C. Test Procedures and Reports:

1. Full details shall be submitted of the scheduled tests and the expected duration of all test procedures. Samples of all test report forms, and full details of the method by which the raw test data is to be reduced, shall be approved before testing is begun on the system (CPLC and 45 High St.) to be furnished under this Contract.

2. The test report shall identify the name of manufacturer, model numbers, serial numbers, and the last date of calibration of test instrumentation. Documentation shall be furnished to verify that test instruments have been calibrated not more than nine months prior to the tests.

3. The test report shall include a list of attendees.

4. Certified test results for the system components (CPLC and 45 High St.) tests shall be submitted within 30 days after the completion of each test. No equipment shall be released for shipment until certified test data is approved by the Authority. Copies of approved test procedures, raw data measured results, calculations and all data derived from tests shall be included as part of report. All test data shall be bound in one report. The test report shall be indexed and cross-referenced in an easily understood manner.

D. Certificate of Compliance: A certificate of compliance that all components furnished meet the requirements specified herein shall be submitted.

E. Operation and Maintenance Manuals shall submitted as listed below:

1. The Contractor shall furnish an operation and maintenance manual for each piece of equipment, unless otherwise specified herein. The following identification shall be inscribed on the cover: the words "OPERATING AND MAINTENANCE MANUAL", the name and location of the project, the name of the Contractor, and the contract number. The manual shall include the names, addresses, and telephone numbers of each subcontractor furnishing or installing equipment. In addition, include the local representatives for each item of equipment. The manual shall have a table of contents and index. The manual shall be assembled to conform to the table of contents, including tab sheets placed before instructions covering the subject. The instruction sheets shall be legible with large sheets of drawings folded in.

2. The Contractor shall submit to the Engineer for approval three copies of the preliminary operation and maintenance manual at least 30 days prior to shipment of first relevant unit that shall provide technical support for tunnel ventilation equipment operation and maintenance. unit. After approval of the preliminary submittal and having made all necessary corrections and amendments required, the Contractor shall provide the Engineer with six additional copies of the approved dated operation and maintenance manuals. One set of master camera-ready copy shall be included as one of the six copies

to permit additional copies to be made. The master camera-ready copy shall be clearly marked as such on the outside. The manual shall provide a clear explanation of the theory, operation, and maintenance of the equipment accompanied by photos and schematic, wiring and mechanical assembly diagrams, as required. The manual shall be indexed and cross-referenced in an easily understood manner. The manual shall be loose leaf bound and shall include, but not necessarily be limited to, the following information:

a. Operating instructions.

b. Troubleshooting and fault isolation procedures for on-site level repair

c. System (CPLC and 45 High St.) equipment removal and replacement procedures.

d. Disassembly and re-assembly instructions.

e. A list of the replaceable components.

f. A test procedure to verify the adequacy of repair work.

g. A preventive maintenance schedule and instructions for the replacement of any electrical equipment, e.g., I/O cards, software, controller cards, etc.

h. A preventive maintenance schedule for inspection, removal, and replacement for each component.

i. A list of special tools provided by the manufacturer.

j. A list of recommended tools and test equipment required performing all maintenance tasks.

k. Recommended spare parts list for one year's operation.

l. Interchangeable parts list-showing parts common to items of equipment.

m. Equipment manufacturers' descriptive literature including catalog cuts.

n. As-built working drawings.

o. System component (CPLC and 45 High St.) approved factory test reports.

p. The latest service bulletins with dates that describe service procedures.

q. The CPLC software programming, trouble shooting, fault diagnostics, and shutdown procedures.

1.04 FACTORY TESTS

A. General

1. The following specifies the testing requirements for the system (CPLC and 45 High St.) components to be procured under this Contract. No tests described herein shall preclude any additional standard test normally performed by the manufacturers for similar equipment.

2. The Contractor shall notify the Engineer in writing of all test dates not less than 14 days prior to tests including the expected duration and sequence of testing. The Engineer or a representative may witness any or all tests unless waived by the Engineer in writing. Observations made during the tests, and test results shall be recorded in a document form approved by the Engineer, certified by the Contractor and submitted to the Engineer. All expenses concerning or incidental to the testing shall be borne by the Contractor.

3. The test procedure specified shall be sequential in the order prescribed. Any system component thereof that fails satisfactorily to perform any test as specified shall be considered unacceptable. Failing parts shall be redesigned and the entire unit shall be re-tested as specified herein.

B. Programmable Logic Controllers:

1. Arrange for factory testing of each CPLC. Tests shall be witnessed and un-witnessed.

2. Witnessed Tests

a. Each redundant CPLC system shall be tested for operation, sequencing, interlocking, communications, diagnostics, fault conditions, data logging and alarming functions as outlined in this Specification and the Contract Drawings. All field contact functions shall be simulated for purpose of this test.

3. Un-witnessed Tests and Checks

a. Check of control and power wiring insulation resistance and freedom from shorts and grounds.

b. All assemblies and components used in CPLC shall be tested including, but not limited to:

(1) Production and conformance tests in accordance with the relevant specified standards.

(2) Temperature cycling tests.

(3) Dielectric withstand capability tests.

(4) Radiated and conducted electromagnetic susceptible tests.

(5) Showering arc tests.

(6) Mechanical stress tests.

(a) Vibration

(b) Shock

(c) Free fall at height of three feet

4. Each CPLC unit shall be subjected to a burn-in test of sixty degrees centigrade for at least ninety-six hours.

PART 2 - PRODUCTS

2.01 COMMUNICATION PROGRAMMABLE LOGIC CONTROLLERS

A. General

1. The Contractor shall furnish, install, and test a complete monitoring and control system, that is programmable logic controller (CPLC) based, in the Communication Rooms (or designated location) to monitor and control various station items. The system shall also contain the necessary hardware and software for automatic monitoring of the fire and security alarm systems, etc. The system shall consist ofGeneral Electric FANUC PLC series 90-30 or approved equal CPLC completely wired with all necessary auxiliaries, and CPLC programming software.

2. Qualifications of CPLC System Manufacturer: The system shall be furnished by a single manufacturer who has actively been installing systems of the required specified capabilities and whose products have operated successfully for a period of at least five (5) years.

3. CPLC Manufacturer: the manufacturer whose name appears on the submittal data shall manufacture programmable logic controller system.

4. The Contractor shall bear full responsibility for ensuring that the system will perform and function correctly as per the specified performance criteria in such a way that the tunnel systems will function properly in full compliance with this Specification.

5. The two completely wired redundant CPLC shall be housed in a freestanding NEMA Type 12 gasketed enclosure with a sealed plastic window to observe the processor and status indicating lights. Cabinets shall be provided with environmental controls to maintain the required operating temperature and humidity in accordance to the component manufacturer's requirements. Environmental provisions shall be as specified below. The CPLC shall be housed in a rack mount type enclosure. Enclosure shall be a minimum of two feet (L) by two feet (W) by eight foot (H), with a document pouch on the door. The enclosure shall be fitted with a back panel onto which the CPLC, modem, power supply, UPS, terminal strip, and 120 VAC disconnect shall be mounted.

6. The system components (CPLC and 45 High St. control equipment) shall be designed for performing discrete and analog control in an industrial environment.

7. All CPLC system (CPLC and 45 High St.) equipment shall be UL listed.

8. The CPLC system manufacturer shall maintain, as part of a national network, engineering service facilities within 250 miles of the Project, to provide start-up service, emergency service calls, repair work, service contracts, maintenance, and training of operating personnel. Emergency service shall be available within twenty-four hours of notification.

9. The Contractor shall develop and implement program software for the CPLC and 45 High St. consoles, based upon the performance criteria detailed herein, and refinement of the general ladder logic diagrams shown on the Contract Drawings.

B. Performance Criteria

1. General: The CPLC system shall allow remote control and monitoring of MBTA systems, in accordance to the application. The CPLC shall monitor and control the specific application of the systems shown on the contract drawings and described on the attached points list in Appendix A. The CPLC on receiving a remote command shall provide any time delays, alternate running patterns, or sequenced starts, necessary for correct running for the controlled equipment.

2. The CPLC system shall allow remote control and monitoring of the tunnel ventilation system and other systems described in the attached points list in Appendix A. These two items are outlined below.

a. The system's primary task shall be for control of tunnel ventilation fans. Manual control shall be accomplished by the Fire Management Panel (existing and new), Remote Control Panel or MCC manual controls.

b. Point of control priority levels shall be as follows:
(1) Local Control at MCC
(2) Remote Control at FMP (existing and new).
(3) Remote Control at Operations Control Center (OCC), 45 High St. 7th floor.

c. The ventilation fan control system shall be manually operated from the MCC, FMP or the OCC.

(1) The MCC shall have the following indicating lights:
Fan trouble (each fan)
Status of each fan, off, forward and reverse
Point of control selection in manual, local and remote (each fan)

(2) The MCC shall include a run time meter for each fan

d. The following indicating lights shall be mounted on the door of the PLC cabinet:

- Fan troubles (each fan)
- Maximum number of fans running
- PLC switch-over to backup
- No PLC switch-over to backup
- Control override by fire personnel
- Control override at remote panel

- MCC in manual (local) control, each fan
- MCC in manual (remote) control, each fan

e. Fan trouble shall be initiated by the following cor1tact closures:

- MCC overload relay activation
- MCC circuit breaker tripped

When the CPLC receives MCC overload relay activation and circuit breaker tripped, the CPLC will illuminate the individual fan trouble icon on the remote 45 High St. display consoles but not shut down the affected fan.

f. The CPLC shall stagger start multiple fans through a time delay of several seconds. The PLC; shall start the first fan, then after a time delay, start the second fan, etc. until all fans required are on line.

g. The CPLC shall allow for a time delay for starting a fan in the opposite direction if it has been running. The time delay shall be adjustable from 20 to 60 seconds and shall allow the fan to run down before starting in the reverse direction.

h. The CPLC shall cycle or alternate the use of the fans for train operation mode to distribute run time evenly on all fans.

i. The CPLC shall monitor and control other systems shown on the contract drawings and described on the attached points list.

C. CPLC General Construction Requirements

1. The programmable logic controller, and ancillary equipment, shall be designed, manufactured, and tested to the latest applicable NEMA, IEC, ANSI, and IEEE standards.

2. The CPLC shall be solid state, modular, and have field expandable design allowing the system to be tailored to the tunnel ventilation control. The design shall have the capacity to allow for the expansion of the system by the addition of hardware and/or software.

3. Modules shall be plugged into a chassis and keyed to allow installation in only one direction. The design shall prohibit upside down insertion of the modules as well as safeguard against the insertion of a module into the wrong slot. The chassis shall be mounted on the enclosure back panel.

4. The CPLC, and ancillary equipment, shall be capable of operating in an ambient temperature range of -40 degrees to 120 degrees Fahrenheit. Communication equipment specifically itemized in section 2.01 A above shall be capable of operating in an ambient temperature range of 32 to 120 degrees Fahrenheit.

5. The entire CPLC, and ancillary equipment, shall function continuously in the relative humidity range of 5 to 95 percent non- condensing.

6. The CPLC shall be designed with proper type; size and quantity of system components to monitor and control tunnel ventilation system in accordance with the specified performance criteria.

7. Each CPLC system shall include, but not be limited to, the following:

   a. I/O chassis.

   b. Redundant central processing unit (CPU).

   c. Redundant power supply module.

   d. Local I/O modules.

   e. Cables.

   f. Interface and Communications Modules

8. The CPLC system shall be designed with local I/O modules, located in the same enclosure of CPLC, to perform all the functions as outlined in this Section.

9. All the CPLC outputs to the various tunnel systems shall be through an interface terminal cabinet (ITC) as required.

10. Each CPLC shall have one dedicated Ethernet communications port that supports remote communications signals.

11. All system modules, main and expansion chassis shall be designed to provide free airflow convection cooling. No internal fans or other means of cooling, except heat sinks, shall be permitted.

12. All modules within the system shall be mechanically interlocked to prevent insertion or removal of modules under power that, in turn, helps to prevent damage to the modules and/or system.

13. In a single chassis system, all system and signal power to the CPU, support modules shall be distributed on a single motherboard or back plane. No interconnecting wiring between these modules via plug terminated jumpers shall be acceptable.

14. All wiring shall be neatly installed and wire ways shall be used wherever possible. All wiring shall be identified at both ends by wire markers.

15. Nameplates shall be provided for each module, device, and equipment with appropriate data such as equipment number, rating, serial number, and manufacturer.

16. Central Processing Unit (CPU)

   a. The CPU shall read the inputs, perform all system logic, conduct on-line diagnostics, and control the outputs. Diagnostics shall include memory checks,

scan time monitoring, and I/O bus monitoring. If a fault is detected, the processor shall stop and turn off the affected outputs.

b. The CPU shall be a self-contained unit, and shall provide ladder rung program execution and support remote or local programming. The CPU shall provide I/O scanning, inter-processor, and peripheral communication functions.

c. The CPU shall give visual indication by illuminating a "green" indicator when no fault is detected and a "red" indicator when a fault is detected.

d. The main CPU front panel shall include a connector that provides inter-processor communication to peripheral support devices. The connector shall support communication to a programming device up to 1,000 cable feet away, at no less than 19.2K baud.

e. The main chassis front panel shall includetwo-color indicators showing the following status information:

(1) Program or Run mode of the CPU.

(2) The run/fault status of the CPU.

(3) Enabled/Disabled state of outputs.

f. Processor mode shall be selected by a key or toggle switch mounted on the front panel of the CPU. The following modes shall be selectable:

(1) RUN: No ladder edits possible, program always executing.

(2) PROGRAM: Programming allowed, program execution disabled.

(3) REMOTE: Programming terminal can make edits and change processor mode, including TEST mode, whereby the logic executes and inputs are monitored, but edits are not permanently active unless assembled at the PLC.

g. The CPU shall have the capability of addressing up to 1024 input and 1024 output points.

h. A minimum of 32K words (16-bit) of internal, solid-state RAM memory shall be provided for storage of the control program. The full memory of the CPU shall be usable for program or data storage. The memory shall be expandable with the addition of RAM memory sub-modules.

i. Program back-up shall be on non-volatile EEPROM memory cartridges.

j. Program functions shall include contacts, coils, timers, counters, math functions (add, subtract, multiply, divide), shift registers, bit, and word operations.

k. The CPU shall include an integral real-time clock, backed up by internal lithium or long term type battery, which can be accessed from the control program. The clock shall include functions for time of day (year, month, day, hour, minute, second), alarm, and operation hours counter.

l. The CPU shall be capable of floating point math calculations including integer to floating point conversion, floating point to integer conversion, add, subtract, multiply, divide, square root and compare.

m. The CPU shall permit changing ladder program or data values while running.

17. Power Supply

a. The programmable controller shall operate in compliance with an electrical service of 120 volts AC, single phase, in the frequency range from 55 to 63 Hertz.

b. The manufacturer shall provide a system power supply capable of converting 120 volts AC line power to the DC power required to operate the programmable controller system.

c. The main power supply and the back-up power supply shall have the capability of supplying power to the CPU and local input/output modules. Auxiliary power supplies shall provide power to remotely located racks.

d. The power supply shall automatically shut down the programmable controller system whenever its output current is detected as exceeding 125 percent of its rated current.

e. The power supply shall monitor the incoming AC line voltage for proper levels. When the power supply is wired to utilize 120 volt AC power, the system shall function properly within the range of 97 to 132 volts AC. If the voltage level is detected as being out of range for more than one-half line cycle, the power supply shall automatically shut down the system and remain disabled until the proper voltage level returns. In addition, the power supply shall provide surge protection, isolation, and outage carry-over up to two cycles of the AC line.

f. Design features of the programmable controller power supply shall include diagnostic indicators mounted in a position to be easily viewed by the user. These indicators shall provide the operator with the status of the DC power applied. In addition, a means of disabling power to CPU shall be possible from a power disconnect switch mounted in a position easily accessible by the operator.

g. At the time of power-up, the power supply shall inhibit operation of the processor and I/O modules until the DC voltages are within specifications.

h. The power supply shall offer fuse protection.

18. Input and Output Modules

a. Inputs and outputs shall be modular. Each module shall have status LED/LCDs for each point.

b. All field wiring shall be to a removable terminal block that will permit pre-wiring of the module, or removal and replacement of a module without disturbing the field wiring or any other I/O modules. All I/O modules shall be firmly attached to the I/O chassis and wired to terminal blocks.

c. All I/O wiring shall be minimum No. 14 AWG, 600 volt.

d. All modules shall be enclosed in rugged housings.

e. All input and output modules shall have faceplates that shall be marked or labeled indicating use.

f. All digital input modules and output modules used for fire personnel control panel indication shall be 120 volts AC and have 16 isolated circuits per module.

g. Analog input modules shall have a maximum of eight isolated differential channels per module with a minimum of 11 bit resolution. Analog inputs shall be 4-20 mA.

h. Analog output modules shall have eight isolated differential channels per module with a minimum of 11 bit resolution. Analog outputs shall be 4-20 mA.

i. All digital output modules used for fan motor control shall be relay contact output type and have 32 outputs per module. Outputs shall be field selectable as normally open or normally closed via jumper setting. Contact shall have one amp. DC rating and be suitable for use as shown on the Contract Drawings.

19. Interface and Communication Modules

a. Control and monitoring links to the control panels shall be provided to support operation as described herein and otherwise detailed on the Contract Drawings.

b. Communications format and protocol shall be as required by the manufacturer of the system provided and must be compatible to the existing NVLPLC protocol.

20. CPLC - Hot Back-Up

a. The CPLC system, which controls the operation of the I/O, is called the primary system. The other CPLC system, which is ready to take control of the I/O in case of failure of primary system, is called secondary system.

b. The capability shall exist for a secondary CPU system to monitor the same I/O data as the primary system. Upon fault detection in the primary system, the secondary shall assume control. During switchover, the output states shall be held in their last state. Upon assuming control, the secondary shall lock out the primary system. Switchover shall take no longer than 50 milliseconds.

c. A local and remote alarm shall be provided when switchover occurs.

21. CPLC Programming

a. The programming format shall be traditional relay ladder diagram.

b. It shall be possible to program a maximum instruction matrix of seven wide by six deep containing as many as 77 examine instructions.

c. The capability shall exist to change a contact from normally open to normally closed, add instructions, change addresses, etc. It shall not be necessary to delete and re-program the entire rung.

d. It shall be possible to insert relay ladder diagram rungs anywhere in the program, even between existing rungs, insomuch as there is sufficient memory to accommodate these additions.

e. The CPLC shall have the capability to remove an entire logic rung into an edit buffer where individual parameters may be easily altered.

f. The system shall have the capability to address software timers and software counters in any combination and quantity up to the limit of available memory. Instructions shall permit programming timers in the "ON" or "OFF" delay modes. Timer programming shall also include the capability to interrupt timing without resetting the timers. Counters shall be programmable using up-increment and down-increment.

g. Timer instructions shall include selectable time bases in increments of 1.0 second and 10 milliseconds. The timing range of each timer shall be from zero to 32,767 increments. It shall be possible to program and display separately the timer's present and accumulated values.

h. The programmable controller shall use a signed integer format ranging from -32,768 to +32,767 for data storage of the counter preset and accumulated values.

i. The programmable controller shall store data in the following formats:

(1) Signed integer numbers ranging from -32,768 to +32,767.

(2) Floating point numbers consisting of six digit mantissa.

(3) Decimal numbers ranging from zero to 9,999.

j. Instructions shall be provided for grouping contiguous 16 bit data words into a file. The system shall address up to 1,000 files with up to 1,000 words per file.

k. At the request of the programmer, data contained in system memory shall be displayed on the CRT programming panel. This monitoring feature shall be provided for input/output status, timer/counter data, files, and system status. Ladder logic rungs shall be displayed on the CRT with rung numbers in sequential

order. However, the programmer shall have the option of selecting and displaying logic rungs non-contiguously.

l. l. The system shall have the capability to enter address comments and symbols.

m. A means to program a fault recovery routine shall exist. When a major system fault occurs in the system, the fault recovery routine shall be executed and then the system shall determine if the fault has been eliminated. If the fault is eliminated, program execution resumes. If the fault still exists, the system will shut down. A user shall have the option to resume operation or to shut down operation upon fault detection.

n. An interrupt routine shall be programmable such that the routine shall be executed regularly.

o. An instruction shall be available to give the ladder program diagnostic information, state control, and sequencing of a ventilation step simultaneously, while allowing the capability of user friendly state programming techniques.

p. An instruction shall be supported to incorporate closed loop control systems.

q. The CPU shall support indexed and indirect addressing of inputs and outputs, along with all data table words (integer, binary, floating point, timers, and counters) for the software instruction set.

r. The system shall support both bit and word level diagnostic instructions.

s. The processor shall be able to edit, build, and execute logically constructed function blocks (steps).

t. It shall be possible to configure up to 16 main control programs which consist of hybrid control functions combining both relay ladder logic and sequential function chart operations. These control programs will all share a common data table. Each control program may be individually inhibited by setting a processor status bit. A processor configuration screen shall be available to permit configuration of the order execution of the control programs.

u. A standard instruction in the programmable controller shall be capable of executing Level 1, Level 2, or Level 3 diagnostics. Level 1 diagnostics use conventional relay ladder logic for control with ladder logic fault detection logic setting fault bits that are monitored by the instruction for diagnostic message generation only. Level 2 diagnostics use conventional ladder logic to control outputs, but the instruction monitors inputs and conditions to detect faults and generate a diagnostic message. In level three diagnostics, the instruction controls output, monitor inputs for state control, perform diagnostic detection, and generates a diagnostic message. The diagnostic logic shall always be current and shall be automatically updated whenever the user's control program is changed.

v. The system shall provide the following types of diagnostics messages:

(1) Status messages.

(2) Error messages.

(3) Time-out messages.

(4) Warning time-out messages.

(5) One valid exit message.

(6) Mismatch message.

w. The programming software shall design a configuration suitable to the tunnel ventilation application herein described.

x. The programming software shall also provide the following functions:

(1) Hot Keys: Keys for short cuts to software functions.

(2) File Management: Create, delete, rename, and merge program files.

(3) Memory Map: Display processor memory usage.

(4) Data Monitor: Display the contents of data files.

(5) Save and Restore: Save processor memory files to disk; restore processor memory files from disk.

(6) I/O Configuration: Configure intelligent I/O modules.

(7) General Utility: Display general system information and clear faults.

(8) Histogram: Display information about specific data locations over time.

(9) Forcing: Force I/O on and off.

(10) Import and Export: Convert database files (which contain symbols, rung comments, instruction comments, and address comments) and processor memory files to ASCII and from ASCII to the programming software.

2.02 REMOTE CONTROL DISPLAY

A. Control and monitoring display ICON's, software additions and modifications, modems, and equipment shall be added at 45 High St. The Contractor is responsible for wiring and additional equipment required at 45 High St. to provide a complete, operating system.

B. Icon commands shall control fans through the CPLC as described in paragraph 2.01B.2.c

2.03 AUXILIARY EQUIPMENT

A. Spares shall be provided for each component in the CPLC system as follows:

1. One CPU

2. Ten Percent (minimum of one) of each type of I/O module.

3. The CPLC system shall be provided with a spare EEPROM memory cartridge containing the control program.

4. One Power Supply.

5. Two modems (one each field and OCC).

6. Cisco 1600-R router with 4MB Memory Card.

7. Communication Module

2.04 HARDWARE

A. Fasteners

1. In accessible areas, fasteners shall be hexagonal head bolts with hexagonal nuts, provided with heavy-duty lock washers.

2. In inaccessible areas, fasteners shall be hexagonal head tap bolts, provided with heavy duty lock washers.

3. Bolts and tap bolts shall be stainless steel and shall conform to the requirements of ASTM A 193, Grade B8M or B8MA, equivalent to AISI Type 316, with suitable lock washers.

4. Nuts shall be stainless steel and shall conform to the requirements of ASTM A 194, Grade 2H, equivalent to AISI Type 316.

B. Anchor Bolts:

1. Anchor bolts shall be stainless steel and shall conform to the requirements of ASTM A 193, Grade B8M or Grade B8MA, equivalent to AISI Type 316, with suitable lock washers.

2. Anchor bolt nuts shall be stainless steel and shall conform to the requirements of ASTM A 194, Grade 2H, equivalent to AISI Type 316.

PART 3 - INSTALLATION

3.01 GENERAL

A. Installation of control system and CPLC shall be in accordance with manufacturers recommendations, approved shop drawings, and as shown on the Contract Drawings.

B. All wiring shall be neatly installed and wireways shall be used wherever possible. All wiring shall be identified at both ends by wire markers.

C. Work required under this section shall include but not be limited to:

1. Furnish and install a complete and operable Communication Programmable Logic Controller (CPLC) based Fire, Security, Tunnel Ventilation, and misc. control and alarm monitoring systems.

2. Furnish and install CPLC equipment and cabinet; terminal cabinet and incidentals and appurtenances necessary to complete the work as specified herein and as shown on the Contract Drawings.

3. Completion and verification of as-built drawings. One paper set to be provided for each CPLC enclosure. One Mylar set for delivery to 500 Arborway. One copy on CD-RW in the latest version of Auto-CAD.

3.02 TESTING

A. Arrange for factory testing of each CPLC. Tests shall be witnessed and un-witnessed.

1. Witnessed Tests

a. Each redundant CPLC shall be tested for operation, sequencing, interlocking, communications, diagnostics, fault conditions, data logging and alarming functions as outlined in this Specification and the Contract Drawings. All field contact functions shall be simulated for purpose of this test.

2. Un-witnessed Tests and Checks

a. Check of control and power wiring insulation resistance and freedom from shorts and grounds.

b. All assemblies and components used in CPLC shall be tested including, but not limited to:

(1) Production and conformance tests in accordance with the relevant specified standards.

(2) Temperature cycling tests.

(3) Dielectric withstand capability tests.

(4) Radiated and conducted electromagnetic susceptible tests.

(5) Showering arc tests.

(6) Mechanical stress tests.

(a) Vibration

(b) Shock

(c) Free fall at height of three feet

3. Each CPLC unit shall be subjected to a burn-in test of sixty degrees centigrade for at least ninety-six hours."

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Sections 16050, BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK and 16801, BASIC SIGNAL TECHNICAL REQUIREMENTS as appropriate.

END OF SECTION

Appendix A

At a minimum, the following control and indication points shall be monitored by the CPLC at each ventilation shaft:

A. Controls
   i. Emergency Ventilation Fans
      1. Fan off.
      2. Fan on supply.
      3. Fan on exhaust.

B. Indications
   i. PLC
      1. AC power fail.
      2. Communication module failure.
      3. UPS failure.

   ii. Emergency Ventilation Fans
      1. Abnormal operation.
      2. Over current.
      3. Under voltage phases A, B, & C.
      4. Phase A, B, & C currents
      5. Fan current monitoring system status
      6. Fire and Smoke.
      7. Intrusion.
      8. Bearing Fault
      9. Motor High Temperature
      10. MCC disconnect position.

   iii. Pumps
      1. AC overload.
      2. AC over temperature.
      3. AC power fail.
      4. AC running.
      5. DC overload.
      6. DC over temperature.
      7. DC power fail.
      8. DC running.
      9. High water.
      10. Low water.
      11. Pump running.

   iv. Emergency Generator
      1. Gas vapor alarm.
      2. Gas vapor spare.
      3. Gas vapor trouble.
      4. Gas vapor warming.
      5. Start failure.
      6. Transfer failure.

7. Gas detector.
8. Generator running.
9. Trouble.

v. Fire
1. Station fire.
2. Fire alarm panel trouble.

vi. Collector's booth
1. Alarm trouble.
2. Telephone line fault.

vii. Intrusions
1. Communication room.
2. Signal room.

viii. Communications Equipment
1. PCM trouble.
2. Fiber Optic equipment trouble.
3. UPS trouble.
4. CCTV equipment trouble.
5. Radio equipment trouble.
6. Ambient temperature.
7. AC power failure.

SECTION 16742

ELECTRONIC SIGN SYSTEM

PART 1 - GENERAL

1.01 DESCRIPTION

A. The work to be performed under this Section consists of furnishing, installing, and testing all of the equipment necessary to form a complete and operational Electronic Sign System. The Electronic Sign System shall display passenger information via Light Emitting Diode (LED) scrolling bulletin boards located on the station platform areas as specified herein and as shown on the Contract Drawings.

B. The sign system shall be an extension of the existing MBTA electronic sign system controlled from the existing VSU Systems.

C. The Contractor shall be responsible to provide necessary software and hardware to integrate the Electronic Sign System with the Public Address System to provide simulcast announcements. Digitally stored Public Address messages within the New Maverick Station Public Address Computer shall be simulcast with LED display messages. The Contractor shall be responsible for design and implementation of the simulcast system.

1.02 QUALITY ASSURANCE

A. The system shall comply with the requirements of the Authority and shall have components listed with U.L.

B. Any modifications or additions to the existing Electronic Sign System equipment or Software at Dewey Control Center to accommodate the new system at New Maverick Station shall be performed by personnel approved by the Engineer and shall be fully coordinated with the MBTA. The Contractor shall take all precautions necessary to insure that the required modifications and additions will not interfere with or inhibit any current Electronic Sign System functions and shall submit all changes to the Authority for Approval .

1.03 SUBMITTALS

A. The Contractor shall submit to the Engineer for approval:

1. Manufacturer cut-sheets and functional descriptions for all Electronic Signage equipment that the Contractor proposed to furnish.

2. Point to point wiring diagrams for all equipment furnished under this Section.

3. All necessary Software Changes.

PART 2 - PRODUCTS

2.01 ELECTRONIC SCROLL SIGNS

A. The Electronic Scrolling Signs furnished under this Contract shall be multi-colored Light Emitting Diode (LED) moving message signs. The signs shall be located as shown on the Contract Drawings. The electronic scroll signs shall meet or exceed the following specifications:

1. Single faced LED sign

2. All solid state design with a microprocessor Controller, 32K resident non-volatile EPROM for firmware, 32 K resident socket to accept non-volatile EPROMs and EEPROMs with in-system programming capability for EEPROMS, battery protected 10,000 character memory, and support hardware.

3. Shall have a communications interface to receive new programs and updates via an RS-232 or RS-422 interface.

4. Shall be provided with a software addressable interface that may be set to one of 15 addressees via DIP style switches within the sign module.

5. Shall be powered from an internal power supply and shall utilize an input voltage of 117 VAC 60 Hz.

6. LED luminous intensity for each discrete LED shall be 9 millicandelas for the red channel, and 15 millicandelas for the green channel. Viewing angle shall be plus/minus 70 degrees (140 degrees total). The red channel shall have a peak wavelength of 640 nm. The green channel shall have a peak wavelength of 560 nm.

7. Each character display matrix shall be 5 x 7 for normal or 6 x 7 for wide font, where each pixel is comprised of four red and four green LEDs.

8. The sign shall have 96 pixels across the display area of 96 inches and 7 pixels down a display area of 6.5 inches. The entire sign shall have a total of 5376 discrete LEDs on the face of the display.

9. The electronic scroll sign shall have a length of 96.2", a height of 9.5" and a depth of 4.5". Access to data and power shall be through the rear of the sign, near the ends.

10. Each scroll sign shall be supplied with an externally replaceable fuse and a six foot three wire 117 VAC single phase power cord.

11. Each scroll sign shall be fixtured with captive hardware to permit attachment to approved enclosures.

12. Each sign shall provide for the external connection of a dry switch closure such that when closed shall cause the internal CPU to display a special message file previously programmed from the Dewey Control Center. This message shall be displayed for the entire duration of the switch closure.

13. The sign shall be designed such that when a sign is powered on after a maintenance or power outage, it shall resume display and message sequence provided that power outage has been less than 24 hours.

B. The Sign Logic and program minimum capabilities of message presentation shall be as follows:

1. Messages shall be capable of traveling across the display screen from right to left at a fixed rate.

2. Messages shall be capable of flashing on and off at a once per second rate.

3. Messages shall be capable of dissolving on and off in a gradual progression.

4. Fixed messages shall be capable of being displayed continuously until the next message is initiated.

5. Messages shall be capable of entering or exiting the screen in a bottom up or top down direction.

6. Message memory shall be non-volatile Random Access Memory (RAM) and shall have the capability to store at least ten messages or 8000 characters. Expansion capacity shall be provided for an EPROM or EEPROM memory to add 31,744 characters of additional non-volatile memory, using low insertion force sockets.

7. The sign shall be capable of storing preprogrammed animated graphic presentations in its RAM memory and in its expansion memory. These presentations shall be triggerable by short control sequences and shall be suitable for standalone usage, or in combination with text supplied at run time.

2.02 SIGN ENCLOSURE

A. The weathertight scroll sign enclosures designed, furnished and installed under this Contract shall be as follows:

1. Shall be fabricated of 20 gauge aluminum extrusions with brackets, attachment frame, and all connections suitable for connecting the sign to the structure as shown on Contract Drawings.

2. Sign lens shall be fabricated of scratch resistant hardened surface plastic which shall be durable and maintainable.

3. Sign lens shall be light grey or bronze similar to Rohm & Mass 2404 or Acrylite 126-4 or approved equal.

4. Sign lens shall slide into the aluminum extrusion.

5. The Contractor shall furnish lens care and cleaning instructions for the lens provided.

6. The enclosure shall have a hinged backing and shall be accessible to maintenance.

2.03 SIGN CONTROL

A. The Contractor shall furnish an interface to the Public Address Computer to be provided under Section 16770.

2.04 CABLES

A. Cable to the electronic signs shall be specified in the cable section of this Specification.

2.05 DEWEY CONTROL CENTER

A. The Contractor shall be responsible for all software changes needed at Dewey Control Center to accommodate the new New Maverick Station electronic sign system.

B. The Contractor shall provide all equipment and connections at 45 High St. Central Control to ensure proper operation of the electronic signs at Maverick Station via the Public Address System as described in Section 16770 of this Specification.

2.06 POWER REQUIREMENTS

A. Power for Electronic Sign System shall be 120 VAC and shall be derived from the Communication Room panel.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Electronic Signs

1. The Electronic Signs shall be installed in the locations as shown on the Contract Drawings. The sign enclosures shall be mounted in accordance with the approved site specific detail plans.

B. Conduit

1. The Contractor shall install all rigid steel conduit in accordance with the approved Conduit Routing Plans.

C. Cable

1. Install all cables within the rigid steel conduit. All conductors shall be identified by color and listing its functions. Cable routing distances between the P.A. Computer and the electronic signs shall be kept at a minimum to ensure accurate RS-422 serial communicator. All cable routing distances shall be approved by the Authority.

D. Control Center

1. The Contractor shall fully coordinate the sign system control modifications with the MBTA. Special care shall be taken to insure that the modifications do not inhibit any

current functions of the existing system.

E. Coordination

1. The Contractor shall coordinate with the electrical Contractor for the provision, location, and access of power for the electronic signs.

3.02 TESTING

A. The Contractor shall notify the Engineer at least five (5) days in advance of the Electronic Sign System test so that the Engineer or his representative may be present at this test if he so elects.

3.03 TRAINING

A. Provide 5 mandays of the services of a factory trained service engineer, for assistance in installation, specifically trained on the type of equipment specified. Mandays listed are exclusive of travel time, and do not relieve the Contractor of obligation to provide additional services required to place the equipment in operation. If the equipment and material has not been installed as indicated and as specified, and additional time of the factory-trained service engineer beyond that specified above is warranted to correct the deficiencies, provide this additional time at no additional cost to the Authority.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16748

RADIO SYSTEMS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies relocation of existing Blue Line, MBTA Police, Boston Fire and Boston Police radio base stations, radiating antenna, combiner cabinet, battery chargers and batteries to the new communications room location.

B. The existing Radio System shall remain fully operational during station construction. The Contractor shall provide to the Authority radio system interim arrangements prior to radio system relocation.

C. It is the Contractor's responsibility to coordinate with the Authority the relocation and installation of existing radio equipment to the new communications room.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16749

FIBER OPTIC CABLE

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies designing, furnishing and installing a singlemode fiber optic cable and ancillary equipment necessary to form a complete and operational fiber optic cable system as shown on the Contract Drawings and as specified herein. The fiber optic cable shall be a singlemode multi-fiber cable, of loose tube construction with twenty-four (24) fibers. The fiber optic cable shall have the following properties:

1. Singlemode fibers (9 um nominal core) with 125 um cladding and 250 um coating/diameter.
2. Dual Window operation at 1300 and 1550 nm.
3. Loose tube design with central strength member.

B. Any optical cable deemed unusable by the Authority shall be removed from the construction site and disposed of, in accordance with Section 16802.

1.02 QUALITY ASSURANCE

A. ANSI/EIA Compatibility

The fiber optic cable provided under this Contract shall conform to EIA-TIA-472D000-A sectional specification for Fiber Optic Communications Cable for Outside Plant Use and EIA-472A sectional specification for Fiber Optic Communication Cable for Outside Aerial Use.

B. Manufacturer Pre-Approval

The Contractor shall submit proposed fiber optic cable manufacturer(s) to the Authority for approval. Approval shall be based on the proposed manufacturers experience in furnishing fiber optic cables for rapid transit and railroad installations and the following:

1. Quality Assurance Program

The manufacture of cables in accordance with the requirements of this Specification shall be accomplished in compliance with a Quality Assurance Program that meets the intent of the ASQC Standard CI-1968; General Requirements for a Quality Assurance Program. Such compliance shall promote a thoroughly tested cable which will render long service life to the user. Prime concern must be focused on the necessary formal assurance requirements to insure that cable failure cannot be attributed to actions or lack of actions by the manufacturer.

2. Warranty

The Contractor shall certify compliance with the following warranty prior to selection of the manufacturer:

a. The Contractor warrants that the design, material, and workmanship incorporated in each item of cable shall be of the highest grade and consistent with the established and generally accepted standards for fiber optic cable used for optical communications systems and that each such item and every part and component thereof shall comply with this Specification.

b. The Contractor agrees that this warranty shall commence with the acceptance of each item of the cable, whether the defect be patent or latent, and shall extend for a period of two years after initial satisfactory operation of the item or four years after acceptance of the item, whichever is shorter.

c. The warranty covering any length of cable that shall be replaced by the Contractor under the above conditions shall be reinstated for a period of two years effective as of the day when said replacement is effected. If the failure is found to be of major importance and affects any other item of cable, the reinstatement of the warranty shall then be extended to cover the item(s) so affected as well, and shall start as of the date of such replacement. The warranty reinstatement provided for in this subparagraph (c) shall apply only to the first replacement or repair of any such item and, in the case of failure of major importance, to the first extension of said warranty to said affected items.

d. The Contractor warrants that 100% percent of the fibers provided in compliance with this Specification and the Contract Drawings shall meet or exceed the specifications set forth herein. The Contractor may, at his option, elect to provide this warranty by providing a percentage of fibers in excess of those specifically required, however these additional fibers shall be provided at no additional cost to the Authority.

e. The foregoing warranties are exclusive and in lieu of all other warranties, written, oral, implied, or statutory.

1.03 SUBMITTALS

A. Manufacturer Information

The Contractor shall submit to the Engineer for approval, information for each proposed manufacturer describing his experience in manufacturing optical cable for rapid transit and railroad applications and his quality assurance program and warranty.

B. Technical Data

The Contractor shall submit complete technical data for the cable and ancillary devices he proposes to furnish. The data submitted shall demonstrate compliance with all optical and mechanical properties specified herein. The Contractor shall submit optical loss budget calculations for each length of fiber optic cable.

C. Factory Tests

Factory tests shall be performed in accordance with Paragraph 3.01.C of this Section. The Contractor shall submit the following:

1. Procedures shall be submitted prior to ordering cable.
2. Results shall be submitted within one week after test completion.

    a. Loss
    b. OTDR

D. Field Tests

Field tests shall be performed in accordance with Paragraph 3.01.D of this Section. The Contractor shall submit the following:

1. Procedures shall be submitted prior to beginning installation.
2. Results shall be submitted within one week after test completion.

    a. Loss
    b. OTDR

E. Installation Plan

The Contractor shall submit, prior to installing cable, the following information for each segment of cable to be installed:

1. Pulling layout including distances and tension calculations, for each section of installation.
2. Pulling equipment and tension monitoring devices.
3. Chronological plan for installing cable, including estimated time for each pull and plan for protecting cable on-reel and in slack loops during installation.

F. Termination Procedures

The Contractor shall submit, prior to installing cable, the following information:

1. Procedure for terminating cable within the fiber distribution panel, including fusion splicing of pigtails.
2. Fusion splice equipment description.
3. Splice and termination testing procedure.

1.04 DELIVERY, STORAGE AND HANDLING

A. All cable shall be shipped on reels, adequately protected from damage in shipment (to include the hazard of reels moving obliquely against each other), by heavy wrapping or wood lagging. The Contractor shall be responsible for any damage to the cable occurring in normal transit. The external protective wrapping shall be secured to insure damage-free shipment.

B. Each length of cable shall be wound on a separate reel. Reels shall be designed and constructed to withstand handling and shall be so designed that both ends of the cable will be secured and accessible but protected from injury. If the inner end of the cable projects through the flange of the reel, the inner end shall be protected by a suitable cover of metal having rounded ends and sides and securely fastened in place to protect the cable end. Both ends of cable on the reel shall be secured in place, to prevent their becoming loose in transit or handling of the reel.

C. The radius of the reel drum shall be larger than the minimum dynamic bending radius of the cable to prevent damage to the cable during reelings. The arbor hole shall admit a spindle 2-1/2 (two and a half) inches in diameter without binding. The reels shall be designated and constructed as non-returnable when drum size and cable weight and volume permit.

D. After acceptance of factory tests, the cable shall be effectively sealed against the entrance of moisture. Both ends of each length of cable shall be protected by wrappings of rubber tape and plastic tape, an effective boot taped or sealed into place, or other suitable means approved by the Authority. The use of friction tape, other than as an external mechanical protection over an adequate rubber and/or plastic tape, shall not be accepted. The cable end protection shall be adequate to protect the cable in shipment and prolonged external storage in the weather (if not immediately employed) without regard to the position of the reel while so stored.

E. Each layer of cable on the reel shall be closely and tightly wound in a uniform manner.

F. An arrow shall be painted on one head of each reel pointing the opposite direction from the outer end of the cable with the words "Roll This Way" employing letters not less than 3/4-inch in height and an arrow not less than six inches in length and 1/2-inch in width.

PART 2 - PRODUCTS

2.01 SINGLEMODE FIBER CABLE

A. Construction

Cable construction other than as specified must be approved by the Engineer.

1. The cable shall be designed for aerial installation.

2. The cable shall be of loose tube design, with 24 fibers evenly distributed among the buffer tubes.

3. The buffer tubes shall be color coded or shall provide a scheme of identification such that the fiber buffer tubes can be easily identified by the field forces without the use of special equipment or tools.

4. When more than one fiber occupies a buffer tube the fibers shall be color coded for identification.

5. All fiber(s) shall be contained within buffer tubes, and each buffer tube shall have an inside diameter much greater than the total diameter(s) of the fiber(s) it supports. Each fiber or group of fibers shall be free-floating within the tubes such that all mechanically or environmentally induced stress placed upon the cable is de-coupled from the fibers.

6. A strength member of Kevlar or glass reinforced plastic shall be central to the cable core.

7. The air within the buffer tubes shall be displaced with a gel to prevent entry by water, and to facilitate free movement of the fiber(s) within.

8. The cable shall have an interstitial filling between the buffer tubes and throughout the remainder of the cable to prevent entry of water.

9. A non-hygroscopic, dielectric binder shall be applied over the cable core. An additional binder of high strength fibers shall be applied as required to meet the tensile strength specifications.

10. The outer jacket material shall be approved by the Authority.

11. The cable shall be provided in continuous lengths. Each fiber shall be pulled from the same optical waveguide form, and shall be free of splices. Optical fibers shall be made from silica, and the use of any other material must be approved by the Engineer.

12. A permanent marking shall be employed on the outer jacket of the cable which shall show the date of manufacture and the Manufacturer's name, the nomenclature Fiber Optic Cable, and the number of strands. A numerical sequence shall be marked on the outer jacket, at intervals to be no greater than ten (10) feet, to facilitate determination of cable length and cable remaining on the reel.

B. Optical Specifications

-	Operational Wavelength:	1,300 nm and 1,550 nm
-	Optical Attenuation:	@ 1,300 nm: 0.5 dB/km @ 20°C @ 1,550 nm: 0.4 dB/km @ 20°C
-	Optical Dispersion:	@ 1,300 nm: 3.5 to 4.5 psec/nm-km @ 1,550 nm: $\leq$ 20 psec/nm-km
-	Zero Dispersion Wavelength:	1,290 to 1,330 nm
-	Fiber Core Diameter:	9 um nominal

- Fiber Coating Diameter: 250 ± 15 um
- Fiber Cladding Diameter: 125 ± 3 um
- Core/Cladding Concentricity: ≤ 1.0 um
- Spot Size: 9.8 um
- Refractive Index Difference: 0.3± 0.5%

C. Mechanical Specifications:

- Crush Resistance: 10,000 N/m, (678lbs/ft) length of cable
- Cable Diameter;

  Outside: 15.1mm (0.59") nominal

- Minimum Bending Radius;

  Installation: 20 x Diameter
  Static: 15 X Diameter

- Temperature;

  Operational: -30° C to + 60° C
  Storage: -40° C to + 60° C (on reel)

- Humidity: 0 to 100%, inclusive
- Tensile Strength;

  Installation: 2,700 N (600 lbf)
  Static: 600 N (135 lbf)

PART 3 - EXECUTION

3.01 INSTALLATION

A. Phased Plan

All optical cable installation shall be accomplished in accordance with the Authority approved plan:

1. Pull locations shall be selected to protect the cable on the reel and in slack loops. The Contractor shall be responsible for protecting cable after working hours where cable installation is not completed during a single shift. Cables damaged due to Contractor's neglect while installing cable shall be replaced by the Contractor at no additional cost to the Contract.

2. Pull lengths shall be designed to allow a 20% margin in cable tensile strength.

3. Continuity of cable shall be maintained between termination or splice locations shown on the Approved Drawings. Additional splices will not be allowed without the prior written approval of the Authority.

4. The Contractor shall notify the Authority in writing at least 24 hours in advance of installation of each section of optical cable.

5. All cable entrance openings in equipment enclosures, houses, rooms and junction boxes shall be sealed with either a compression type fitting or pliable sealing compound after the cable is in place. Sealing compounds for rooms, houses, walls, or other partitions shall be fire retardant per ASTM E-814. Sealing compound shall be used to seal the area around cable where the cable emerges from the end of a conduit, pipe, duct bank, or innderduct. All spare conduits shall be sealed or plugged in an approved manner.

6. A suitable lubricating medium, harmless to the cable jacket, shall be used when pulling cable into conduit, pipe, duct bank or innerduct.

7. Any deviations from the approved plan shall be submitted in writing to the Engineer. Any deviation from the approved plan will not be allowed without the prior written approval of the Authority.

8. The Contractor shall, at all times, conduct the installation of the fiber optic cable in complete conformance with the recommended practices of the approved cable manufacturer, and shall not exceed the tensile ratings, minimum bending radius, or any other fiber-optic cable installation restriction.

B. Termination

1. At in-line splice locations, the cental strength member and cable jacket shall be attached to the splice enclosure.

2. Fusion splicing shall be performed by qualified personnel utilizing a splicer equipped with Local Injection and Detection (LID) to optimize splices. The loss across each spliced fiber shall be less than or equal to 0.1 dB at 1300 nm.

3. The Contractor shall notify the Authority in writing at least 72 hours in advance of splicing or terminating each section of optical cable.

C. Factory Tests

1. Cable shall be tested on-reel prior to shipment.

2. End to end loss shall be recorded for each fiber at 1300 and 1550 nm.

3. OTDR with hardcopy record shall be provided for each fiber, at 1300 nm.

4. Optical dispersion shall be tested for each fiber.

5. Certified copies of tests results shall be submitted to the Authority.

D. Installed Tests

1. Tests shall be performed after installation is complete.

2. Optical attenuation from FDP to FDP shall be recorded.

3 Optical Time Domain Reflectometer (OTDR) records including hardcopy, for both direction of transmission shall be furnished to the Authority.

4. All fibers shall be tested.

a. OTDR tests shall be performed utilizing a pulse suppressor such that the FDP termination shall be shown.

b. The loss across each connector and splice shall be shown.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16760

PASSENGER ASSISTANCE EMERGENCY CALL SYSTEM

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the provisioning of a station Passenger Assistance Emergency Call System. Equipment shall be compatible with the existing Passenger Assistance Supervisory System located at Authority's Police Station at 240 Southampton Street and with the Authority's maintenance terminal located at 500 Arborway.

B. The audio path between New Maverick Station and the Police Station shall be via Verizon analog Centrex telephone service. A maximum of three Passenger Assistance Units shall be connected to one Centrex telephone circuit.

C. Location of passenger assistance units shall be as indicated on the contract drawings for station design. Locations shall conform to the Americans with Disabilities Act (A.D.A.) standards.

D. The Contractor shall be responsible for programming each unit and updating the software/database on each supervisory and maintenance computer.

E. Major components of the Passenger Assistance System shall include, but not be limited to, the following equipment as shown on the Contract Drawings:

1. Passenger Assistance Units.
2. Police Assistance LED Sign.
3. Uninterruptable Power Supplies.
4. AC/DC power converters.
5. Wiring and cables.
6. Mounting hardware, conduit, connectors, and any other miscellaneous hardware.

1.02 REFERENCE STANDARDS

Comply with the applicable standards for organizations referenced in Section 16050, Basic Technical Requirements.

1.03 QUALITY ASSURANCE

Provide a Passenger Assistance System proven as adequate and reliable and to meet the requirements of this Section.

1.04 SUBMITTALS

Submit descriptive literature, including manufacturer specification sheets, for all Passenger Assistance equipment and materials proposed for use in accordance with the requirements of Section 01300, Submittals and this Section for approval prior to fabrication, assembly, installation and testing. Also, submit the following to the Engineer for approval:

A. Block diagram of complete system, illustrating proposed configuration and interconnections.

B. Prior to ordering any equipment required under this Section, submit six (6) copies of the following to the Engineer for approval:

1. Full technical data and manufacturer cut sheets for all equipment.
2. Site specific plans showing details of the following:

   a. Passenger Assistance unit location and mounting details.
   b. Cable and conduit details.
   c. Communication room equipment layout.

C. Provide maintenance instruction manuals to the Engineer including information regarding installation and maintenance as follows:

1. Operational Description and Procedures
2. Troubleshooting and Routine Test Procedures
3. Adjustments and Alignment Procedures
4. Wiring Diagrams, Tables and Schematics

D. Prior to installing any equipment, submit to the Engineer for approval six (6) copies of a detailed test procedure intended to ensure all components of the system are functioning properly, in accordance with these Specifications and the Contract Drawings. The tests performed shall include, but not be limited to, the tests outlined in Paragraph 3.02 of this Section. The detailed test procedure shall include a description of all test equipment to be used, and specific pass/fail criteria for each test.

PART 2 - PRODUCTS

2.01 MATERIAL

A. All material shall be new and unused and the workmanship shall be in accordance with the highest standards of the electronic equipment industry. Bids will be accepted only for new and current equipment. Equipment discontinued by the manufacturer will not be accepted. All components shall be UL listed.

B. Equipment purchased under this Section shall be covered by EIA/TIA standards and the manufacturer's warranties against material and workmanship commencing from the date the Authority accepts the Passenger Assistance System for the period noted on the manufacturer's warranty or for a minimum of one (1) year, whichever is greater.

C. Provide all equipment capable of operating within a transit system environment, subject to temperature, humidity, vibration, and light conditions typically encountered.

2.02 PASSENGER ASSISTANCE UNITS

Passenger Assistance Units provided under this Section shall meet the following requirements:

A. The Passenger Assistance Unit shall be a microprocessor based, programmable, flush mount, no handset, full-duplex speaker telephone with a front panel of stainless steel. Depressing one of two buttons shall activate the Passenger Assistance Unit. One button for information requests, the other for

emergency calls. The emergency button shall have a diameter of ¾ inch or greater. The buttons will have no moving parts to jam or seize. The front panel shall be sealed and impervious to water, dust, and spray. The speaker and microphone shall be protected from vandalism by mesh screens. The internal electronics shall be encapsulated with a military specified protective coating to protect against moisture and dust accumulation.

B. The Passenger Assistance Unit shall be fully A.D.A. compliant as specified in ADAAG 4.10.14 and ASME 17.1. Two LED indicators shall be incorporated in the front panel, one to show that a call has been placed, and the other to indicate that it has been answered. The Passenger Assistance Unit shall incorporate stainless steel raised lettering and grade 2 Braille to aid the sight impaired persons in identification. The Passenger Assistance Unit shall have the ability to record and play two different, separate voice messages.

C. The Passenger Assistance Unit shall be programmable from any touch tone telephone (including security codes) and shall have four telephone number (zero to twenty digits, including pause) auto dial capability for each button (help and information), in addition to a programmable maintenance number. The Passenger Assistance Unit shall employ call progress monitoring to detect whether a call has been successfully placed in order to ensure timely call completion. The Passenger Assistance Unit shall have the option to automatically respond to far end call termination signals. When the receiving agent hangs up the Passenger Assistance Unit shall automatically place itself back on hook. The Passenger Assistance Unit shall have an automatic number identifier. The Passenger Assistance Unit shall have auxiliary output contacts that may be remotely or locally activated.

D. The Passenger Assistance Unit shall have the capability to store two separate voice messages. One message shall be played after the emergency button call is answered; the other after the information button call is answered.

E. The Passenger Assistance Unit shall be powered from 5 to 24 VDC (VPP A705 Power and Distribution Module, or equivalent) and shall be provided with a 120 VAC UPS (Sola/Hevi-Duty EGS Electrical Group Sola Series 3000 interactive UPS, or equivalent). In addition, a rechargeable Nickle-Cadnium backup battery capable of operating the Passenger Assistance Unit for four hours shall be provided. The battery shall be trickle charged from the input power source. The Passenger Assistance Unit shall utilize a backup battery warning call feature. If the source of power is interrupted and the unit is on battery for fifteen minutes, the unit shall place a warning call. The unit shall automatically go off-hook and dial a separate maintenance number, wait for an answer and then notify the call party (i.e., by audio tones.).

F. The Passenger Assistance Unit shall be compatible with all features of the existing Vandal-Proof Products PR1150 supervisory and maintenance systems employed by the Authority. These systems provide remote supervision, event logging, reports, and diagnose functions.

G. The Passenger Assistance Unit shall be surface or pole mountable with the addition of an enclosure and/or pole mounting hardware. The enclosure shall provide additional protection from weather. At outdoor locations, the enclosure shall have an overhange to provide additional protection. The Passenger Assistance Unit shall have a neoprene gasket around the perimeter to ensure a waterproof seal. The Passenger Assistance Unit shall be mounted to the enclosure with a minimum of six stainless steel tamper proof screws. The enclosure shall be 16 gauge, 304 stainless steel minimum. The enclosure shall have "EMERGENCY" stenciled on each side.

H. At locations where required a blue Illuminated LED sign shall be provided displaying "Police Assistance" on both sides. The LED sign shall be heavy duty in design, suitable for both indoor and

outdoor applications with dimensions as required by the A.D.A. The blue LED sign shall remain on at all times and be rated for continuous duty. A.C. power for the unit will be derived from the Communication Room electrical panel.

I. The Passenger Assistance Unit shall communicate via a Centrex dial tone as provided by Verizon. A maximum of three units shall be connected to a single Centrex telephone circuit. Each unit shall be accessed separately on the same telephone circuit via password codes. The contractor shall be responsible for all wiring and connections.

J. The contractor shall be responsible for updating all databases/software utilized in conjunction with the Passenger Assistance Unit system.

K. Mechanical Specifications

1. Faceplate Dimensions: 12" x 8" x 2.5" (± 0.5 ").
2. Front Panel: 12 gauge, 304 stainless steel. Minimum six mounting holes. Screws to be tamper resistant, as approved by the Authority.
3. Connector: 2 auxiliary outputs, 1 RJ-11, 1 Power.
4. Weight: approximately 5-7 pounds.
5. Operating Temperature: -20° C to +60° C.

L. Electrical Specifications

1. Telephone connection: RJ-11 modular jack.
2. Max Loop Resistance: 1500 Ohms (loop start operation).
3. Power: 5.5 to 25 VDC or derived from 110 VAC (power transformer to be provided). For multiple unit installations, provide a bulk power supply to power all units.
4. REN: 1.1.
5. Signaling: tone or pulse.
6. Frequency Response: 300Hz to 3,000Hz.
7. FCC registered.
8. Strobe Flash Rate: 80 flashes/minute.
9. Peak Candlepower: 750,000.
10. Power Consumption: 120 VAC – 0.5 amps.
11. Outputs: Optically isolated, solid state, normally open contacts. Maximum DC resistance drop of 35 ohms at a current of 120 milliamperes.
12. Voice Message Length: minimum of 18 seconds

2.03 POLICE ASSISTANCE UNIT STANCHION

For outdoor locations where the high visibility presence of an emergency call box is required utilize a stanchion type housing per the following:

1. Dimensions (approx.): 10 inches wide X 10 inches deep X 114 inches high.
2. Wall Thickness:3/16 in. hot-rolled steel.
3. Finish blue powder-coated.
4. Power Rating (Light): 120 VAC input / 7 VAC output.
5. "EMERGENCY" is to be silk-screened vertically, white lettering, on all four (4) sides. Silk screening shall be covered in protective clear coating.
6. Shall have a blue strobe light on top of unit with the following:

a) Weatherproof design.
b) Light to remain illuminated at all times.
c) Light will flash when unit is activated until end of call.
d) Flash Rate: 65 FPM.
e) Bulb Life (Constant on): 10,000 Hours.
f) Bulb Power (Constant on): 14 Watts.

7. Stanchion is to be capable of housing two (2) loud speakers for local Public Address announcements or sirens.
8. Police Assistance Unit faceplate shall be illuminated for night-time use.
9. Station name and location shall be engraved lettering filled in black on the front of Stanchion, as approved by the Engineer.
10. Stanchion is to be weatherproof.

2.04 WIRE AND CABLE

Provide two pair, 22 gauge solid conductor, shielded twisted pair communication cable from the Communication room telephone terminal board to each Passenger Assistance Unit for use within the Passenger Assistance System.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install Passenger Assistance Units in locations with the orientations as approved on the contract drawings.

B. Install supporting equipment in cabinets and on racks, in the station communication room as shown on the contract drawings.

C. Provide required software modifications to the existing supervisory software at the M.B.T.A. police headquarters (240 Southampton Street), and all additional monitoring locations.

3.02 TESTING

A. Conduct electrical tests to demonstrate compliance with this Specification and with manufacturer's recommended test procedures as approved by the Engineer.

B. After installation is complete, verify proper operation of all control as described herein. Notify the Engineer minimum of five days in advance of test. Engineer or authorized representative reserves the right to attend testing.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16770

PUBLIC ADDRESS SYSTEM

PART 1 - GENERAL

1.01 DESCRIPTION

A. The public address (PA) system for New Maverick Station amplifies voice announcements from collector booth page control boxes, an equipment rack control panel, locally stored messages within the public address computer, and from the Operations Control Center (OCC) and distributes the announcements to passengers via loudspeakers.

1. System inputs shall be balanced and transformer-isolated;

2. System inputs shall be prioritized to prevent simultaneous announcements;

3. Input lines shall be muted when not in use;

4. Power amplifiers shall provide contact closure to CPLC system upon failure;

5. Cable facility to OCC shall be via fiber optic communication cable;

6. Processed and balanced line-level audio output and a prioritized contact closure shall be provided to the input of the priority system for override purposes;

7. A public address computer shall fully interface with the electronic signs described in Section 16742 and the PA speaker control. This computer node shall be designed to produce and deliver to the local PA ADA compliant audio/visual simulcast messages based on pre-recorded menu of messages.

B. In addition to the PA system as specified herein, a PA computer shall provide the capability for digitally pre-recording voice messages and transmitting them to the PA system in order to provide high audio quality.

C. The PA system shall also incorporate an automatic remote test system as specified herein.

D. The Contractor shall be responsible for furnishing, installing, and testing all necessary equipment needed to interface the MBTA equipment at 45 High St. to the new equipment being furnished as shown on the Contract Drawings and specified herein.

1.02 QUALITY ASSURANCE

A. Contractor Qualifications

1. Shall be primarily engaged in the supply, installation, and maintenance of commercial-duty sound systems;

2. Shall be authorized by the manufacturer of the equipment supplied for the supply, installation, and maintenance of that equipment;

3. Shall employ factory-trained personnel for the assembly, installation and maintenance of this system;

4. Shall maintain a service facility stocked with spare parts, service manuals, and test equipment sufficient to efficiently repair this system and its comprising elements;

5. Shall maintain its service facility within 50 miles of the installation site;

6. Shall otherwise demonstrate capability to successfully complete this portion of the Contract as required by the Engineer.

B. Manufacturer Qualifications

1. Shall be a firm whose primary function is to manufacture commercial duty sound products;

2. Shall authorize contractors for the supply, installation, and maintenance of their products;

3. Shall provide the following support services:

a. Contractor training;

b. Periodic Contractor review for technical performance;

c. Service and maintenance manuals, including schematic information and parts lists;

d. Factory stock of replacement parts;

e. Factory repair service.

C. Equipment Requirements

1. Shall be standard products employed in similar installations;

2. Shall have been available for installation over a period of two years or more;

3. Shall be shop tested before assembly into system to confirm products meet or exceed manufacturer parameters for:

a. Functional capability and control range;

b. Electrical gain;

c. Self-generated noise;

d. Frequency response;

e. Distortion;

f. Freedom from RFI, EMI and other interference;

4. Equipment rack and control panel subassemblies shall be shop-tested before delivery to installation site.

1.03 REFERENCES

A. National Electrical Code;

B. Massachusetts Electrical Code;

C. "Chapter 15, Installation Practices," Sound System Engineering, Don and Carolyn Davis, Second Edition, Sams/Bobbs-Merrill, Indianapolis, 1987.

1.04 SUBMITTALS

A. Submit within 90 days of Contract Award, and before commencing acquisition or assembly of materials:

1. Two copies of listing of past projects demonstrating the Contractor's ability to perform this work, to include:

   a. Completion dates of the projects;

   b. Names and locations of the projects;

   c. Nature of the work performed for each project;

   d. Approximate value of the work performed for each project;

   e. Names, addresses, and telephone numbers of key persons owning, operating, designing or bearing other responsibility for each project who can attest to the success of the installation;

2. Certification that the installing Contractor maintains a fully equipped service organization within 50 miles of the installation site;

3. Six copies of bill of materials proposed for this project, to include:

   a. Item's specification reference number;

   b. Item's specification description;

   c. Item's manufacturer and model number;

   d. Manufacturer descriptive literature for each item, including performance data;

   e. Quantity of each item proposed;

   f. Underline all items proposed as alternates to that equipment specified;

B. Submit within 90 days of Contract Award, and before commencing acquisition or assembly of materials, six copies of:

1. AC power requirements for all equipment;

2. Heat generated by all equipment when operating at 10 dB below full rated output, in BTU/hr;

3. Block diagrams showing proposed equipment interconnection;

4. Proposed rack elevation relative to room arrangement;

5. Proposed mounting methods for loudspeakers and other items of substantial weight;

6. Details for Contractor-fabricated items, to include:

   a. Drawings or samples illustrating the proposed size, shape, panel layout, color, finish, labeling, and other pertinent characteristics;

   b. Electrical schematics and parts lists;

   c. Technical descriptions of parts comprising the fabrication.

   d. Detailed riser and wiring diagram.

C. Submit six copies of the following information upon completion of the installation:

1. Functional flow diagrams illustrating component connection, with switches, relays, controls, and cable designations referenced by number;

2. Rack elevation;

3. Nominal control settings illustrated as pictorial representations of the equipment items' control panels;

4. Fabrication details, with switches, relays, controls and other devices referenced to the functional flow diagram;

5. Data describing manufacturer produced equipment, to include:

   a. Manufacturer's descriptive literature;

   b. Manufacturer's operating manuals;

   c. Manufacturer's servicing information including schematics and parts lists.

6. System test and measurement data described in Part 3, Section 3.03 and 3.04;

7. Bind in three-ring loose-leaf binders and include a Table of Contents and tabbed dividers separating each section;

8. No consideration will be given to partial information submitted from time to time.

1.05 DELIVERY, STORAGE AND HANDLING

A. No secured facilities exist at the site for unattended storage of materials.

B. Refurbish or replace damaged materials as directed.

1.06 SCHEDULING

A. Coordinate work to avoid conflicts with other trades which may be working concurrently.

1.07 WARRANTY

A. The system and its comprising elements shall be guaranteed against defects in materials, workmanship and installation adjustment for a period of one year from the date of acceptance.

B. Repair or replace the defective item within 24 hours of notice of failure.

PART 2 - PRODUCTS

2.01 GENERAL

A. This Section is based upon equipment manufactured by Altec Corporation, Oklahoma City, Oklahoma. Ivie or Shure equipment shall be considered as equal.

B. Cable shall employ identical color coding throughout system.

1. Microphone Control Cable: Six-pair, No. 22 AWG, stranded, each pair aluminum-polyester foil shielded with drain wire, overall PVC jacket, nominal O.D. 0.355 inch.

2. Loudspeaker Cable: One-pair, No. 16 AWG, stranded, PVC jacketed, nominal O.D. 0.255 inch.

2.02 EQUIPMENT

A. Equipment Rack

1. No. 16 gauge CRS side panels, No. 12 gauge top and bottom, welded construction;

2. Combination knockouts on top and rear, above and below the door opening;

3. Filtered ventilation openings at top, bottom and on side panels;

4. Front and rear double-wall doors;

5. Cylinder lock in each door, keyed to Authority standard configuration;

6. Front and rear adjustable panel-mounting rails, drilled and tapped for 10-32 mounting screws;

7. 64-3/4 inches of vertical panel mounting space;

8. Furnish with steel blank and perforated ventilation panels to fill unused panel space;

9. Furnish with internal AC power distribution strip and switched incandescent work light;

10. Middle Atlantic WRK-37SA with SB-Series blank panels and VT-Series ventilation panels or equal by Amco or Hammond Industries;

11. Maximum ambient air temperatures at the top of cabinet shall not exceed the equipment manufacturer's recommended maximum temperatures.

B. Mixer

1. Modular six port mixer/pre-amplifier with built-in compressor/limiter;

2. Gain controls, signal presence and peak overload indicators for each port;

3. Master gain control, bass and treble tone controls, tone control defeat switch, output clip indicator, loss-free line input and output receptacles, auxiliary output receptacle, main output transformer balanced and isolated and switchable to microphone or line-level;

4. Input modules programmable for microphone or line-level sources, quantity as required;

5. Input modules transformer balanced and isolated, remote mutable and with continuously variable input gain trim, high and low pass filtering, and screw terminations;

6. Performance:

a. Inputs: 0.1 mVrms sensitivity , 600 ohms impedance;

b. Tone Controls: $\pm$12 dB at 100 Hz; $\pm$12 dB at 10 KHz;

c. Link: 100 mVrms input sensitivity; 10 Kilohms input impedance; 100 mVrms output level; 600 ohms output impedance;

d. Outputs: (main) 600 ohms impedance, +10 dBu line-level, -40 dBu microphone level; (auxiliary) 600 ohms output impedances, 0 dBu level;

e. Frequency Response: (main output) 30 Hz to 20 KHz, $\pm$1 dB, at +10 dBu output level;

f. Harmonic Distortion: (main output) less than 0.1%, 50 Hz to 20 Hz, +10 dBu output level;

g. Noise: (main output) less than -85 dBm A- weighted re: +10 dBm;

h. Compressor/Limiter Threshold: 0 dB to +20 dB, continuously variable;

i. Compressor/Limiter Compression Radio: 1:1 to infinity:1, continuously variable;

j. Compressor/Limiter Release Time: 1 sec. to 6 sec., continuously variable;

7. Altec 1700C or approved equal by Electro-Voice or University.

C. Equalizer

1. Microprocessor controlled with non-volatile memory;

2. No internal or external filter controls, programmable only by external means;

3. 14 analog filters on ISO center frequencies from 63 Hz to 6.3 KHz;

4. Performance:

a. Filter Range: $\pm$6 dB or $\pm$12 dB in 0.5 or 1 dB steps, respectively (selectable).

b. Input Impedance: 15 Kilohms.

c. Output Impedance: 10 Kilohms.

d. Input Sensitivity: 0.775 Vrms.

e. Output Level: 0.775 Vrms.

f. Frequency Response: 20 Hz to 20 KHz +0/-1 dB.

g. Dynamic Range: Greater than 105 dB.

5. Altec 8715A or approved equal by Electro-Voice or University.

D. Automatic Level Control (ALC)

1. Noise-operated automatic level adjustment device;

2. Microprocessor-controlled,including non-volatile built-in calibration software and EEPROM memory;

3. Switchable microphone- or line-level paging input;

4. 70.7 Volt loudspeaker load used as noise sensor;

5. Performance:

a. Gain Control Range: -20 to +20 dB, continuously variable;

b. Noise-to-Gain Ratio: 2:1 to 1:2, continuously variable;

c. Sample Interval: Greater than 800 mSec, automatic;

d. Frequency Response: 20 Hz to 20 kHz, +1/-0 dB;

e. Total Harmonic Distortion: Less than 0.05 percent at 2 KHz with unity gain;

f. Noise: Less than -70 dBm with unity gain;

g. Inputs: (microphone) -80 to -30 dBV input level, greater than 1.8 Kilohm balanced input impedance, greater than 60 dB CMRR; (line) 0 to +18 dBV input level, greater than 40 Kilohm balanced input impedance, greater than 40 dB CMRR;

h. Output: 200 ohm balanced output impedance, +24 dBm maximum output level into 600 ohm load;

i. Gain: +6 dB into balanced load;

6. Furnish with security cover;

7. Symetrix 572 or approved equal by Altec, Electro-Voice or University.

E. Amplifier

1. Comprised of mainframe/card-cage, input transformers, and input, power supply module and power amplifiers;

2. Mainframe to accept eight power amplifier modules;

3. Amplifiers to operate independently and in paralleled, bridged, and/or parallel/bridged combinations;

4. Amplifiers to provide contact closure to SCADA II system upon failure;

5. Performance:

a. Power Output: 78 watts per module or greater with 70 Volt load;

b. Frequency Response: 1 dB, 20 Hz to 20 KHz;

c. Noise: less than -95 dB, A-weighted;

d. Total Harmonic Distortion: Less than 0.1 percent at full power;

e. Input Sensitivity: 0 dBu for full output;

f. Input Impedance: 15 Kilohms;

6. Altec 2280A mainframe/power supply with 15015A input transformers, 2285A input module, and 2271 power amplifier modules or approved equal by Electro-Voice or University.

F. Monitor Panel

1. Comprised of selector switch, matching transformer, volume control, and loudspeaker;

2. Selector switch: 2-pole, 4-position minimum;

3. Matching Transformer: 2.5 Kilohm primary, 8 ohm secondary, 2 watt capacity;

4. Volume Control: 2 watt capacity;

5. Loudspeaker: 8 ohm impedance, three inch or larger;

6. Altec 1698 or approved equal by Soundolier or Toa.

G. Platform Loudspeaker

1. Surface column mounting and submergence-proof;

2. Removable and self-draining bell;

3. Plastic-impregnated, linen-based diaphragm, fungicide treated;

4. Two inch voice coil;

5. Performance:

a. Power Capacity: 25 watts;

b. Sensitivity: 103 dB, four feet, one watt;

c. Frequency Response (-6 dB): 650 Hz to 4 KHz;

d. Dispersion (-6 dB): 95 degrees at 2 KHz;

6. University MM-2 Series or approved equal by Atlas or Electro-Voice Inc.

H. Platform Loudspeaker Matching Transformer

1. Primary Impedance: 10, 5, 2.6, 1.3 Kilohms and 670 and 335 ohms, selectable;

2. Power Capacity: 15 watts;

3. Frequency Response: 50 Hz to 10 KHz;

4. Insertion Loss: 1 dB maximum;

5. Dimensions: 1-15/16 inch high by 2-3/8 inch wide by 1-7/8 inch deep;

6. University 5015 or approved equal by Atlas or Electro-Voice Inc.;

I. Loudspeaker (Lobbies and open public areas)

1. Directivity-controlled weatherproof paging projector;

2. Phenolic diaphragm with 1-1/2 inch voice coil;

3. Integral 70.7 volt matching transformer;

4. Swivel base for flexible orientation;

5. Performance:

   a. Power Capacity: 30 watts;

   b. Sensitivity: 107 dB, one meter, one watt;

   c. Primary Impedance: 2.7, 1.4 Kilohms and 670, 335 and 167 ohms, selectable;

   d. Frequency Response (5 dB): 400 Hz to 6.5 kHz;

   e. Nominal Dispersion (-6 dB): 60 degrees horizontal and 40 degrees vertical;

6. University PA430T or approved equal by Atlas or Electro-Voice Inc.

J. DC Power Supply

1. 24 Volt, one ampere, regulated;

2. 117 VAC, 60 Hz, 75 watt main supply;

3. Fused on both primary and output;

4. Performance:
   a. Ripple: 0.5 mV, RMS;

   b. Regulation : 500 mV, no load to full load;

5. Soundolier S24-2R, EQ/W PS-RK shelf, or approved equal by Acopian or Lambda.

K. PA System Automatic Remote Test Equipment

1. The PA system shall have test equipment capable of allowing remote testing of all PA zones via the Public Address Computer system. This test equipment shall meet the following specifications:

   a. Test equipment shall be mounted in a chassis separate from the rest of the PA equipment and in a 19 inch rack mount in the PA cabinet;

   b. Test equipment shall meet the same environmental requirements as the rest of the PA equipment;

c. Test equipment chassis shall be connected to the station Public Address Computer serial port and be electrically and protocol compatible with the Public Address Computer;

d. Test equipment shall be capable of simultaneously sampling up to eight PA zones. Sampling characteristics are as follows:

1. 12 bits plus sign, linear resolution;

2. Amplitude range: 120 volts;

3. Minimum sampling rate per zone of 20,000 samples per second;

4. Minimum 2,045 point sample of all eight zones simultaneously;

5. 3 dB input filter characteristics set at 50 Hz to 3,000 Hz;

e. Test equipment shall, on command from an Public Address Computer and upon detecting audio energy in the PA zones:

1. Sample the eight input zones;

2. For each of the zones, execute a 2,048 point Fourier transform;

3. Transmit the following information from the transform for each of the eight zones:

a. The average value;

b. The magnitude of all frequency components greater than 120 percent of the average value of the Fourier transform magnitude;

f. On command from the Public Address Computer, the test equipment shall execute a complete test of it's own circuitry including injection and measuring of a test signal into all inputs.

L. High Quality Digital Recording and Transmission

1. General

a. Provide an addition to the Authority's PA system which shall allow the Authority's personnel at the OCC to trigger public address video/audio messages at selected stations throughout the Authority. These broadcasts are to be recorded and stored locally within the Public Address Computer and triggered per a schedule at 45 High St. It is the intent of this Specification that the Authority will be provided with a means to make public broadcast messages of high quality.

b. Equipment and functions to be provided under this Specification shall in no way inhibit, and be entirely compatible with the Authority's existing and new PA systems. At no time during installation and testing, cause the Authority's PA system to

become inoperable.

2. Functional Description

a. OCC

1. The existing IBM compatible computer which now controls the Authority's PA system is to be retrofitted to include a means of communicating with the new Maverick Station Public Address computer. This shall enable the PA console operator to trigger locally stored digital audio/video messages and download new messages when required.

b. Field Equipment

1. The field PA computer equipment shall store, on a non-volatile medium, public address video/audio messages transmitted from the OCC via high speed data link. In addition, the PA computer shall broadcast scheduled stored video/audio messages and live OCC messages via the local station public address broadcast equipment.

3. Equipment Description

a. OCC

(1) The equipment to be added to the control computer at the OCC shall provide the following as a minimum:

Four wire bridging equipment wired to the Main Distribution Frame at 45 High St. This shall provide a high speed data communication to the Maverick Station PA computer.

Software shall be integrated into the existing control equipment computer in such a manner as to not disrupt the existing control programs and to provide operator interface similar to what the Authority now uses.

b. Software Functions

(1) Provide the operator with the capability to record and playback messages at the OCC;

(2) Provide the operator with the capability to select the sites from which the messages are to be transmitted;

(3) Provide the software necessary to transmit, via High Speed Data Link, the message data to the selected remote sites.

c. Field Equipment

(1) Provide the necessary computer hardware to store the message data and broadcast it on command at New Maverick Station. The equipment

provided shall be compatible with the Authority's existing Public Address Computers, both electrically and physically;

(2) The field equipment shall provide the Authority with the capability of storing no less than 40 minutes worth of message data;

(3) If the Contractor chooses to use a hard disk at the remote site to store the data, this is acceptable to the Authority, provided the following criteria are met:

(a) The hard disk assembly shall be mounted within the dustproof enclosure as Authority's existing Public Address field Units.

(4) The field equipment shall provide digital-to-analog conversion with the following parameters:

(a) 44,000 samples per second;

(b) 16 bit samples;

(c) At least 15 KHz $\pm$ 3 dB audio bandwidth;

(d) Signal-to-noise ratio of at least 40 dB.

2.03 FABRICATION

A. Local starter and collector's booth control boxes:

1. Fabricate as follows:

a. Six inches by eight inches by three and one-half inches, stainless steel, JIC type wiring box with clamp cover and continuous hinge:

1. Labeling - Directly engraved and white paint filled cover or engraved black laminate plate with white lettering bolted to cover;

2. Finish - Brushed clear;

3. Mounting - Horizontal with hinge at lower edge;

4. Furnish with keyed lock;

2. Components:

a. Barrier Strips: One Cinch-Jones 4-140 and one Cinch-Jones 8-140, Kulka, Amp or approved equal;

b. Switch: 3-pole, 3-position rotary, Stackpole 73-1041, Grayhill, Alco or approved equal;

c. Switch Knob: 1-1/2 inch pointer, Clarostat P-120, Waldon, Alco or approved equal;

d. Diodes: IN4001;

e. Matching Transformer: 70 Volt to eight ohm, one and two watt, Soundolier L30-T, Electro-Voice, McMartin or approved equal;

f. Volume Control: five Kilohm, audio taper, two watt, Soundolier HX42-5K, Centralab, Lowell or approved equal;

g. Loudspeaker: four inch square, eight ohm, four watt, weatherproof, Misco DC4WP-8 , Quam or Soundolier or approved equal;

h. Grille: Stainless steel, fine perforations, 40 percent open;

i. Microphone: Close-talking, hand-held, low-impedance, push-to-talk, with normally shorted microphone element and normally open DC control contacts, Altec D91P or approved equal by Electro-Voice or University;

3. Assembly:

a. Swedge loudspeaker mounting studs to inside of front cover;

b. Sandwich grille between loudspeaker and cover;

c. Mount microphone clip with tamperproof hardware;

d. Mount volume control within enclosure with no direct access with cover closed;

e. Dress and strain-relief microphone cable through bottom of enclosure;

f. Terminate wiring to barrier strips with spade lugs. Solder all other connections.

B. Equipment Rack Control Panel

1. Install paging selector switch, mute closure relay, microphone, microphone receptacle, and power supply status indicators on panel;

2. 19 inch by 5-1/4 inch by 1/8 inch aluminum rack-mounted panel:

a. Labeling - Directly engraved and white paint filled;

b. Finish - Brush texture and black anodized;

3. Components:

a. Barrier Strips: One Cinch-Jones 4-140 and one Cinch-Jones 8-140, Kulka, Amp, or approved equal;

b. Switch: one-pole, four-position rotary, Stackpole 73-1005, Grayhill, Alco, or approved equal;

c. Switch Knob: 1-1/2 inch pointer, Clarostat P-120, Waldon, Alco, or approved equal;

d. Diodes: IN4001;

e. Microphone Receptacle: Panel-mounting XLR-3F type, Switchcraft D3F, Cannon, AKG, or approved equal by Cannon or Neutrik;

f. DC Status Indicators: LED, green, with integral mount, Alco SLD-853G, Waldon, Grayhill, or approved equal;

g. Relay Mute Closure: Sigma, P&B, Guardian or approved equal;

4. Assembly:

a. Bolt barrier strip to rear of panel;

b. Bolt microphone receptacle to panel;

c. Install switch and relay on panel and terminate on barrier strip;

d. Terminate DC status indicators to 4-140 barrier strip and microphone and DC control wiring to 8-140 barrier strip. Terminate wiring to barrier strips with spade lugs. Solder all other connections.

C. OCC Remote Page Control Circuit:

1. Interface remote paging circuits as required at existing VSU paging system;

2. The system shall sense simplexed DC current on OCC remote page line over the range of one Volt to 40 Volt;

3. The system shall block DC from entering the assigned mixer input;

4. The system shall trigger priority, muting and zone circuits;

5. The system shall restore priority, muting and zone circuits upon interruption of simplexed DC current.

D. Priority and Muting Circuit

1. Shall sense triggering voltage from local starter and collector's booth control boxes, Equipment Rack Control Panel and OCC Remote Page Control Circuit;

2. Shall prioritize audio inputs in the following order:

a. Local starter control boxes;

b. OCC remote page;

c. Collector's control boxes;

d. Equipment rack control panel;

3. In the absence of a page announcement, shall:

a. Lift all source lines from mixer inputs;

b. Short all mixer input lines;

c. Reduce all mixer input gains to 60 dB below full output;

d. Place the ALC in auto-adjust mode.

4. In the presence of a page announcement, shall:

a. Terminate the paging source to the assigned mixer input;

b. Lift the short from the assigned mixer input line;

c. Restore the gain of the assigned mixer input channel;

d. Latch the ALC to the adjusted system gain at the time the announcement is initiated.

5. Upon the conclusion of a paging announcement, shall restore the conditions described in 2.03.D.3 above.

PART 3 - EXECUTION

3.01 GENERAL

A. The Contractor shall utilize conduit as indicated on the Contract Drawings. Where conduit is required under this Contract, provide separate conduit for:

1. Microphone (-80 dBm to -20 dBm) and DC control cable;

2. Line-level (-20 dBm to +30 dBm) cable;

3. Loudspeaker (+30 dBm and above) cable;

4. AC power wiring.

B. Microphone Control Cable

1. Do not splice.

C. Loudspeaker Cable

1. Splice only at loudspeaker terminations.

2. Do not bus commons.

3. House vertical risers in conduit. Splice only within junction boxes.

D. Cable Dressing

1. Separate loudspeaker wiring from AC power wiring by three feet when running parallel.

2. Cross power wiring only at right angles and with loop providing separation of at least six inches.

3. Support lateral wiring to prevent contact with building appurtenances and to prevent stress.

E. Equipment Rack

1. Shop fabricate all internal rack wiring.

2. Terminate all external lines entering rack to barrier strips using spade lugs. Label and transfer labeling to as-built drawings.

3. Use one-pair, No. 20 AWG, stranded, foil shielded cable for internal line-level wiring.

4. Mount equipment rack as shown on approved drawing(s).

5. Float rack from building conduit system.

F. Information Booth Boxes

1. Mount as shown on approved shop drawings.

G. Loudspeakers

1. Mount as shown on the Contract Drawings. Install platform speakers and LED signage in conduit tubing as indicated in these Specifications and as indicated on the Contract Drawings.

2. Tap each loudspeaker matching transformer to draw two watts of audio power; tap lobby loudspeakers to draw 3.7 watts.

3. Wire alternating platform loudspeakers as two separate circuits.

4. Permanently mark each platform loudspeaker assembly as to its circuit, A or B.

5. LED sign power wiring shall be isolated from PA speaker and LED sign control wires/cables within the conduit tubing by either routing through separate compartments or by installing the power wire in aluminum conduit.

6. All wires and cables shall be installed in separate RGS conduits from end of tubing to new CR.

7. Submit detailed plans for speaker/LED signage installation, mounting and location to the Engineer 45 days prior to installation for approval.

3.02 FIELD QUALITY CONTROL

A. General

1. Provide diagnostic equipment to perform the system tests and measurements: sound level meter, calibrated test microphone, function generator, impedance bridge, audio oscilloscope, 1/1-octave real-time frequency spectrum analyzer, and AC-VTVM or digital voltmeter.

2. Diagnostic equipment manufactured by Bruel & Kjaer, General Radio, Hewlett-Packard, Tektronix, Ivie, Sound Technologies, and similar manufacturers will be acceptable for these tests; non-professional equipment or shop-assembled kits will not be accepted.

3. Acceptance of the public address system is contingent upon the system meeting or exceeding the test and measurement criteria described in 3.03 and in 3.04 following. Ensure that the performance requirements are met by providing the test equipment described above and by recording on-site measurements as required.

B. Before loudspeaker installation:

1. Measure the impedance of each loudspeaker/transformer assembly at 1 KHz. Reject any assembly measuring below four Kilohms.

C. Before terminating loudspeaker lines:

1. Inspect the polarity of each loudspeaker assembly, changing polarity as required to bring all loudspeakers into common polarity.

2. Measure the impedance of the load presented to each amplifier at 250 Hz and at 4 KHz. Disconnect and correct any load which measures below the rated load impedance of the amplifier. Record the final measurements.

3. Terminate the output of each amplifier to a load resistor whose value is equal to that of the associated loudspeaker load. Drive the amplifier with a 1 KHz sinewave signal. Adjust each amplifier channel to produce maximum output with 0.5 percent THD or less.

   a. Measure and record the signal level required to achieve maximum output.

   b. Measure and record each amplifier's output power.

   c. Compute and record each amplifier's voltage gain.

   d. Inspect each amplifier's output by observing the display of the oscilloscope set to ten mV per vertical division for the absence of signal distortion. Note any discrepancies, correct the source, and retest as required.

D. Before adjustments:

1. Bypass the equalizers and automatic level control.

2. With a 1 KHz sine-wave signal driving a line-level input, adjust each subsystem to produce the sound pressure level specified in 3.03.A.3 following. Sweeping the signal from 200 Hz to five KHz, inspect each loudspeaker assembly for rattles, buzzes and other mechanical noises. Correct any noises generated within the system and retest. Report any noises generated by building fixtures or other sources external to the sound system to the Engineer.

3. With the measuring microphone connected to the real-time analyzer and with pink noise driving each amplifier channel, walk each loudspeaker subsystem to determine representative positions for the measurement of frequency response.

4. Set the real-time analyzer for 1/1-octave, one dB per vertical increment, and slow response. While driving a line-level input with pink noise, adjust each subsystem to produce 20 dB above the area's ambient noise level. Record the un-equalized frequency response of each loudspeaker subsystem at the representative positions.

E. Following adjustments:

1. With the subsystems set to their nominal levels, disconnect the system's microphones. Resistively terminate the mixer input lines at the microphone termination points. Engage each signal channel by removing line shorts, input muting, and all other protective measures.

2. Connect the oscilloscope to the outputs of the amplifiers and set it for ten mV per vertical division.

3. With all lighting and HVAC systems in their normal operating modes, inspect each signal channel for hum, hiss noise, and outside interference by observing the oscilloscope display. Correct any noise greater than 60 dB below the output the amplifier when the amplifier is driven to full output and with less than 0.5 percent THD. Retest as required and record the noise readings. Restore the system to normal operating conditions.

3.03 ADJUSTMENTS

A. Engage the equalizers.

1. Adjust each equalizer's high-pass filter for roll-off at 160 Hz.

2. Adjust each equalizer to produce the following acoustic frequency response:

Center Frequency	Relative Level	Level Tolerance
250 Hz	-14 dB	+/- 2 dB
500 Hz	-8 dB	+/- 2 dB
1,000 Hz	-2 dB	0 dB
2,000 Hz	0 dB	+/- 2 dB
4,000 Hz	-6 dB	+/- 2 dB

Roll-off frequencies beyond this spectrum at 12 dB per octave or greater.

3. Using the real time analyzer with the settings described in above, record each loudspeaker subsystem's acoustic resones at the representative positions.

4. Using the real time analyzer with the same settings, record the electrical response of each equalizer.

5. Adjust the platform subsystem to produce 95 dB-SPL and the mezzanine subsystems to produce 90 dB-SPL.

6. Engage the automatic level control and adjust it for a dynamic noise range of 25 dB.

7. Balance the system's gains and losses as necessary to produce the required sound pressure levels and automatic level attenuation. Freedom from amplifier clipping and system distortion shall be maintained.

8. Record all control settings.

3.04 TESTING

A. All testing shall be done in accordance with Division I and as stated herein.

3.05 TRAINING

A. Provide 5 mandays of the services of a factory trained service engineer, for assistance in installation, specifically trained on the type of equipment specified. Mandays listed are exclusive of travel time, and do not relieve the Contractor of obligation to provide additional services required to place the equipment in operation. If the equipment and material has not been installed as indicated and as specified, and additional time of the factory-trained service engineer beyond that specified above is warranted to correct the deficiencies, provide this additional time at no additional cost to the Authority.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16780

COMMUNICATION ROOM BASIC REQUIREMENTS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing, installing, and placing in operation a communications room. All communications equipment, hardware, electrical, HVAC, and ancillary devices required for a complete Communication Room, as described herein and shown on Contract Drawings, shall be the responsibility of the Contractor.

B. Prior to demolition of existing communications room, the new communications room shall be built and all equipment (new and relocated) shall be fully operational.

1.02 QUALITY ASSURANCE

A. Submit proposed manufacturers of equipment, per the relevant specification sections, to Engineer for approval. Past performance and experience shall be a factor in evaluating each proposed manufacturer, in part. Additional criteria will be:

1. Quality and capability of equipment;

2. Manufacturer support;

3. Technology utilized, system flexibility, and features;

4. Ability to furnish and install within required time frame.

B. Manufacturers shall provide a one-year warranty on all equipment furnished and installed. The Contractor shall maintain this warranty, extending to system acceptance or one year after equipment is placed into service, whichever is later.

C. Manufacturers of equipment shall be in compliance with a quality assurance program that meets intent of ASQC Standard C1-1968; General Requirements for a Quality Assurance Program. Compliance shall promote thoroughly tested equipment that will render long service life. Manufacturer shall focus prime concern on necessary formal assurance requirements to ensure equipment failure cannot be attributable to actions or lack of actions.

D. Make all arrangements with equipment suppliers to perform functional factory demonstration and acceptance tests on all equipment supplied. Notify Engineer at least fourteen (14) days in advance of all tests so that Engineer may, at his option, be present for required tests.

E. Monitor manufacturers to assure that approved Quality Assurance Program is closely adhered to and that equipment is manufactured in accordance with specifications and approved submittals.

1.03 SUBMITTALS

A. Submit manufacturer data sheets and other descriptive information sufficient to determine compliance with this Specification to the Engineer for approval prior to ordering equipment.

B. Within one week after completing each test, submit two copies each of complete test results to the Engineer.

C. Submit the following drawings to the Engineer for approval:

1. Detailed layouts of each terminal board;

2. Layouts for each location;

3. Cross-connect details for each location;

4. Cabling for each location;

5. Details of interconnections to other equipment;

6. Network management system detail.

PART 2 - PRODUCTS

2.01 GENERAL

A. Provide the Authority with a complete Communication Room. Responsibility for communications systems operations shall rest with the Contractor.

1. The Communications Room shall be as shown on the Contract Drawings. There shall be sufficient room to install all floor and wall mounted equipment racks and cabinets while maintaining full access to all equipment. Provide sufficient space to locate future equipment racks and cabinets.

2. At a minimum, the Communication Room shall be sized to contain the following equipment:

a. FM-200 Fire Suppression System.
b. Fire Alarm Control Panel (FACP).
c. Closed Circuit Television Cabinet.
d. Public Address and Visual Message System Cabinet.
e. Circuit Breaker Panel.
f. Telephone.
g. Pulse Coded Modulation (PCM) System / SONET System Rack.
h. Battery and Charger Rack.
i. Communications Junction Box (CJB or AJB)
j. Fiber Optic Cable Slack Enclosures (2 minimum)
k. Fiber Optic Cable Distribution Panels (1 per Fiber Optic Cable Slack Enclosure)
l. Communication Programmable Logic Controller (C-PLC) rack
m. C-PLC Intermediate Distribution Frame (IDC C-PLC).
n. Passenger Assistance System

3. The Communication Room shall consist of equipment listed herein and as shown on Contract Drawings. Include special cables, ladder trays, and miscellaneous equipment necessary to provide fully operational Communication Room.

4. Components shall be UL listed.

5. The Contractor shall follow the EIA/TIA and NEC standards.

2.02 FIRE PROTECTION

The Contractor shall furnish and install a FM-200 fire protection system. The system shall conform to the latest Boston Fire Department Codes and Section 16200 of these Specifications.

2.03 RISER CABLING

The Contractor shall furnish and install 24 AWG copper twisted-pair telephone riser cable color coded to match standard PIC cable, shielded with binded aluminum and jacketed with plenum-rated material, Lucent Technologies ARMM type or approved equal. Riser cable shall contain sufficient pairs to serve all telephone/data outlets in the station/building. Riser cabling shall be terminated in the telephone room(s) on all floors in multiples of 50 pairs based on the formula of four pairs per outlet plus 100% spares.

2.04 CROSS-WIRE

Provide one 1000 foot spool of 24 AWG single pair cross-wire per distribution frame location. Cross-wire tip conductor to be colored white and the ring to be colored blue. In addition, provide a mounting for each spool of cross-wire.

2.05 MAIN DISTRIBUTION FRAME

The Contractor shall furnish and install a Main Distribution Frame (MDF) with separate voice and data Krone type disconnect blocks for termination of the station/building risers and wiring terminals, station outlets, PCM, ancillary equipment, and telephones. Include hinged orange covers with block identification and pair assignments clearly and neatly identified. Riser cables shall be terminated on the inside row of terminal block (top terminals if 200 pair blocks are utilized). Installation shall include all necessary accessories for mounting the blocks, as well as ladder racks, trays, rings, and accessories for holding or attaching cables and jumpers.

2.06 POWER

A. The Communication Room shall have a dedicated circuit breaker panel. The panel shall be located within the Communications Room.

B. The Contractor shall compute the power requirements for the equipment powered via this panel. The panel shall then be configured for 150% of the power requirements. This shall include a minimum of 20% circuit breakers.

C. The circuit breaker panel shall be on the emergency generator circuit.

2.07 EQUIPMENT RACKS AND CABINETS

A. All floor mounted equipment racks and cabinets shall be set on a three inch concrete pad.

B. Key cabinets like existing cabinets currently install in Authority locations.

C. Cabinets shall be rated NEMA 12.

D. Cabinet doors shall be permanently labeled as to function.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Furnish and install all material and equipment to form a complete and operational Communications Room as specified within these documents and shown on Contract Drawings, in accordance with all manufacturer's instructions, and in compliance with National Electric Code standards, EIA/TIA standards 568A, 569 570, 606 and 607, and all applicable Commonwealth of Massachusetts local codes and ordinances.

B. Affix permanent tags at both ends of cables designating cable function, piece of equipment connected to, and receptacle designation.

C. Install all wiring in rigid steel conduit where required.

D. Identify all conductors by color code and listing its function.

E. The Contractor shall coordinate, schedule, and obtain all required system connection and testing with M.B.T.A. Communication Department.

F. The Contractor shall mark or permanently identify each terminal block or station outlet with the same identification code or number that shall appear on the as-built drawings. The Contractor must complete identification of all devices before final inspection and acceptance. Labeling shall conform to EIA/TIA standard 606.

3.02 SYSTEM CONFIGURATION AND ACCEPTANCE

A. Prior to system acceptance, furnish a complete set of as-built drawings and documentation to include the following:

1. Line drawings of all installed equipment in AutoCAD format;

2. Step-by step installation checklist specifying cabling runs and applicable installation tests;

3. System interconnection instructions;

4. Acceptance test procedures;

5. Documentation and acceptance test procedures for network management system.

3.03 FIELD TESTING

A. Furnish all test equipment required, and perform all necessary tests, to ensure all equipment within the Communications Room are functioning properly in accordance with the intent of this Specification.

B. Each device shall be tested in the presence of the Contractor and MBTA Telecommunications Department. Upon completion of the test, a certified test report shall be submitted for approval.

C. Any system deficiencies observed under testing shall be noted in the initial certified test report. All deficiencies shall be corrected and system shall be retested. A subsequent certified test report shall be submitted.

D. Test complete systems with the Authority as required. If any deficiencies are observed, correct same as described herein. Contractor shall submit as-built drawings and maintenance manuals and spare parts one week prior to final scheduled testing by the Authority.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16801

BASIC SIGNAL TECHNICAL REQUIREMENTS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the basic requirements for signal work to be performed by the Contractor in modifying the Blue Line signal system at Maverick Station. The work shall be performed without interruption of revenue service. The Contractor shall provide a complete and safe operating signal system, fully compatible with the existing operating signal system.

B. Further description of the concepts and the actual listing of work may be found in the SUMMARY of WORK Section and throughout the 16800 series of specification sections.

C. Wherever the following terms are used within the signal sections of these Specifications, the intent and meaning shall be:

1. Removal - The removal of existing facilities shall include, but not be limited to the dismantling and disposal, or dismantling, protection, and delivery to the Authority as specified herein or as directed by the Engineer.

2. Relocation - Relocation of existing facilities shall include, but not be limited to, the following:

   a. Detailed design and submittal for approval of materials, mounting hardware, installation drawings, description of methods and procedures required for the relocation of the existing signal facilities to a new location;

   b. Dismantling, protection and off-site storage of existing facilities;

   c. Furnishing and installation of all new mounting hardware, cables, and raceways;

   d. Installing, testing and placing in service of signal facilities at the designated and approved locations.

3. Furnishing and Installation - Furnishing and installing new facilities shall include, but not be limited to the detail design, submittal for approval, furnishing, installation, protection, testing, and placing in service, including all required cables, connections, raceways, supports, and mounting hardware.

D. The Contractor shall protect all existing, new and relocated signal, communication and signal power facilities for the duration of construction as specified herein and within the Protection of Work and Property Section of these Specifications. The Contractor shall ensure that his installation methods provide for full protection of the signal facilities and do not interfere with construction and train movements.

E. The Contractor shall furnish and install removable protective structures to preclude any damage to signal facilities during demolition and construction. When protection in place is not sufficient or not feasible the Contractor shall remove and reinstall signal facilities as described under the Relocation term as approved by the Engineer and at no additional cost to the Contract.

F. Any equipment, cables, and structures damaged during construction shall be replaced with identical

material, tested, and placed in service by the Contractor in accordance with these Specifications and as approved by the Engineer. Any resultant costs or delays to the project shall be full responsibility of the Contractor.

G. Any work performed on the existing signal system shall be completed, tested and placed back in service prior to the beginning of daily revenue service. The Contractor shall coordinate and stage his work to prevent any interference with the mainline operation of trains. Any impact to the normal operation of trains that results from the Contractor's activities shall be full responsibility of the Contractor, including the cost of manual block train operation.

H. To avoid interruption of revenue service, the Contractor shall maintain sufficient quantities of signal cable and other materials and products to enable replacement of any signal facilities that may be damaged within project limits.

I. Signal cables shall connect signal facilities without junction boxes or splices, except as specified herein or shown on the Contract Drawings.

J. The Contractor shall participate and be a party to system certification by the Commonwealth of Massachusetts, Department of Communications and Energy (DTE) for the modifications to the ABS system, as directed by the Engineer. During the system verification process, the Contractor shall have his technical representatives on the property, at locations specified by the Engineer, in order to take immediate corrective action due to system failure, improper operation, or improper installation, if any. Five complete sets of test charts, cut-over circuits, cut-over procedures, and proposed drawing modifications shall be provided to the Authority sixty days prior to the system cutover.

K. The Contractor shall note that some Contract Drawings are typical. The Contractor shall provide the detailed design as application of the typical drawings to his equipment including, but not limited to, assignment of terminals, cables, contacts, repeater relays, installation layouts, site specific details, alternative and additional equipment proposed to be provided.

L. The Contractor shall furnish all new as-built drawings for the systems furnished, installed, modified or relocated as part of this Contract.

M. The Contractor shall prepare and submit proposed method of phasing his work and scheduling of cut-overs in full compliance with the Authority's Supplementary Conditions included within these Specifications.

N. The Contractor shall prepare all in-service bulletins in the standard Authority's format prior to cut-overs. The Contractor shall submit a sample in-service bulletin for review and approval by the Authority.

1.02 SITE CONDITIONS

A. The Authority believes that information on the Contract Drawings describing the existing facilities pertinent to this Contract is correct insofar as it is shown. The Authority does not guarantee or represent that the Contract Drawings conform to existing signal facilities. It shall be understood that conditions may exist which are contrary to the conditions indicated by the existing system plans and that the Contractor assumes all risks regarding the cost or quantity of the work to be done because of any use, which he may make of them. The Bidder shall visit the site and satisfy himself by visual inspection alone, as to existing conditions. The Authority will allow no claims for additional cost because of the Contractor's unfamiliarity with observable site conditions.

B. The Contractor shall obtain from the Authority the latest copy of as-built drawings. The Contractor shall reproduce existing drawings for his use at no cost to the Authority. Existing as-built drawings shall not be removed from the Authority's property.

C. Before performing any work, the Contractor shall field verify that existing as-built drawings are up to date and consistent with existing field conditions. Any difference between the record as-built drawings and existing field conditions shall be reported and submitted to the Engineer. The field condition shall take precedent over the record as-built drawings, unless otherwise directed by the Engineer.

D. General

1. Dust, dirt, varying weather conditions, and electrical interference shall be considered and reflected in the design of all systems, subsystems, equipment and components.

2. Work under this Contract shall be performed along the tracks, in equipment rooms, in stations & tunnels, at the OCC at 45 High Street, and at other locations as defined in these Specifications.

E. Operating Environment

3. The MBTA's OCC provides around-the-clock, centralized management of heavy rail, light rail, and surface transportation. This centralized management shall continue without interruption during the entire period of the Contract.

4. The Contractor shall be familiar with this type of operation and be experienced in installing new control systems without interrupting MBTA operations. Cut-overs or any work that may result in unavoidable interruptions to existing operating systems shall be performed during non-revenue hours (1:30 a.m. to 4:30 a.m.), and shall be coordinated with the MBTA via the submittal process, detailing schedule and installation procedures.

5. At no time shall any action by the Contractor cause the Authority's transit system to lose the ability to perform any of its functions.

F. Physical Environment

6. Electrical Requirements

a. All equipment provided shall be compatible with the Authority's electrical power supplies and distribution system.

b. All equipment provided shall operate in its intended environment without causing or suffering harmful interference due to of electromagnetic emission or response.

c. All equipment provided shall be capable of withstanding source power fluctuations of plus or minus 20 percent of rated voltage, and plus or minus 10 percent of rated frequency, unless otherwise specified.

7. General Environmental Requirements

8. Unless otherwise specified, all equipment provided shall be designed to operate without degradation under the following conditions:

   a. Subjection to a single shock with a peak acceleration value of 30 meters per second per second;

   b. Subjection to a single shock with an equivalent height of fall of 25 millimeters;

   c. Maximum design concentrations of fire retardant chemicals employed in the areas in which the equipment is installed.

1.03 QUALITY CONTROL

A. It is the responsibility of the Contractor to provide safe, reliable and fully compatible modifications to the required portion of the Blue Line signal system.

B. It shall be understood that the omission from these Specifications, or from the Contract Drawings of any part or item which is required to for the safe and orderly execution for the construction work shall not relieve the Contractor from his obligation of furnishing, installing, removing, relocating, and protecting all required material and appurtenances.

C. Establish and maintain an approved Quality Assurance Program for all work and materials referenced in these Specifications. This program shall comply with all the provisions required in Section 01400, Quality Control, of these Specifications.

D. AREMA Communications and Signals Manual, Section 2 "Railway Signal Systems" and "Instructions for Making Tests of Signal Apparatus," shall prevail as a standard.

E. FRA "Rules, Standards, and Instructions for Railroad Signal Systems," Part 236, and Testing Systems, Part 234, shall prevail as regulations.

F. If a conflict exists between standards and regulations as specified herein, the most restrictive in the opinion of the Engineer, shall govern.

G. All signal work shall be done by a qualified electrical contractor, experienced in the design and construction of automatic train protection systems with automatic train stops as presently utilized on the Blue Line. The Contractor's qualifications shall include a list of at least five completed similar projects, resumes of key individuals and references.

H. The Contractor shall employ a qualified on-site Signal Engineer for the duration of the project. The Signal Engineer shall be familiar with rapid transit operations and signal system construction to direct the installation of the signal work as described herein. The proposed Signal Engineer shall have a minimum of ten years of design and construction experience in transit signaling.

I. At the first project meeting, the Contractor shall submit resume of the Signal Engineer for the Authority's approval. The Authority retains the right to interview the proposed Signal Engineer before approval. Signal work will not be allowed to commence without Authority's approval of the Signal Engineer.

J. The Contractor shall provide a 24 hour-a-day, 7 day-a-week point of contact to the Authority for reporting trouble related to the Contractor's work and he shall be prepared to respond within two hours

of contact by the Authority.

1.04 REGULATORY ELECTRICAL REQUIREMENTS

A. The Contractor shall comply with the electrical requirements of all national, state and local codes, laws and ordinances, and all rules and regulations of public administrative authorities having jurisdiction over the work where the requirements do not conflict with these Specifications.

B. The latest published issues of the standards, codes, recommendations or requirements of the following listed organizations in effect at the date of the Notice-To-Proceed where the requirements do not conflict with these Specifications. In case of a conflict, the more stringent shall apply.

AASHTO	American Association of State Highway and Transportation Officials
ANSI	American National Standards Institute
AWS	American Welding Society
AREMA	American Railway Engineering and Maintenance of Way Association
ASTM	American Society for Testing and Materials
ICEA	Insulated Cable Engineers Association
IEEE	Institute of Electrical and Electronic Engineers
IES	Illuminating Engineering Society
MEC	Massachusetts Electrical Code
NEC	National Electrical Code
NEMA	National Electrical Manufacturer's Association
NESC	National Electrical Safety Code
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
UL	Underwriter's Laboratories, Inc.

1.05 SUBMITTALS

A. Submit documentation to the Engineer in accordance with the requirements of Section 01300, Submittals, and other applicable Sections of these Specifications.

B. A resume of the Signal Engineer shall be submitted for approval by the Authority.

C. Submittals required for the materials and installation methods for work to be performed under this Contract are specified within the respective sections of this Specification. All submittals shall be site specific, and shall indicate the application and purpose of the equipment proposed.

D. It is responsibility of the Contractor to maintain a submittal log. The Contractor shall update and provide the Engineer with four copies of the submittal log on a bi-weekly basis.

E. The work plan shall be submitted to the Engineer on a weekly basis.

F. The Contractor is allowed to resubmit any rejected submittal once. If the Authority does not approve submittal for the second time or if the amount of rejected submittals exceeds 35% of the submittals required by the Contract, the cost of the further review shall be borne by the Contractor. The amount the Contractor is charged for review of excessive submittals shall be equal to the cost of review to the Project.

G. Every submittal must be approved by the Engineer before material fabrication, delivery and (or)

installation. Any cost of material, system or service furnished and (or) installed without Engineer's approval shall be borne by the Contractor.

H. Modifications to the signal system shall be submitted in the same format as existing as-built record drawings. New signal drawings shall use the same symbols and nomenclature as the existing as-built drawings. New drawings shall match and reference existing as-built drawings for adjacent locations.

1.06 ADJACENT CONTRACTS

A. The Contractor shall note that other construction contracts are in progress within the limits of this Contract and simultaneous to this work. The Contractor shall coordinate and cooperate with all other contractors, including schedule coordination, access to the site, maintenance of security, temporary facilities, cleaning of the site, and like matters requiring common effort.

B. The Contractor shall coordinate his work with the Authority's maintenance activities.

1.07 DELIVERY, STORAGE AND HANDLING

A. Provide all equipment and accessories specified herein and all accessories not specifically identified but which are deemed necessary or which are reasonably required to make a complete and well integrated system within the scope of this Contract.

B. Deliver a complete system including all hardware, components, accessories and documentation to the work site and assure that the equipment is adequately protected during shipment.

C. Identify all major units with the Authority's contract number and station destination. Upon receipt, inspect all items and verify they are in working condition. At the time of shipment, provide the Engineer with a listing of all items not shipped.

D. Provide adequate bracing to protect equipment from damage during shipment. Provide enclosures to prevent damage during shipping and handling. Ship equipment in a manner to ensure a minimum amount of labor is required to complete the installation and to configure the system into its final state.

E. The delivered equipment shall include all wire and cabling required between the physical components of the system, including all interconnecting wires, cables, connectors, and terminations required for subsystem elements, interconnections, interfaces, and main power source attachment.

F. Provide each separate item of the system, including cabinets, chassis, modules, cables, cards, etc., with identifiable nameplates, tags and/or markings. These markings shall contain at minimum the part number and serial number. DYMO type labels are not acceptable.

G. Provide equipment storage in a secured facility approved by the Engineer and assume all associated costs.

H. Replace any equipment damaged in transit, storage and caused by mishandling at no additional cost to the Contract.

1.08 WARRANTY

Provide warranty on equipment and systems provided under this Contract, in accordance with MBTA Division 1, Section 00700, General Conditions, Article 2.08, Warranty of Work. Costs associated with

work, services, and materials to provide such warranty will be considered included in the Contract amount and no extra payment will be made. Proper operation of existing and new systems during construction activities associated with this Contract is required. Material repairs required during the construction period will be considered part of the normal construction work. This general requirement supersedes any lesser warranty or guarantee. Where applicable, extended warranty and maintenance requirements are identified throughout these Specifications.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Provide material and apparatus as specified in these Specifications and as shown on the Contract Drawings.

B. Provide new products and components that are free of manufacturing defects. Provide electrical components rated to operate at power, voltage, current and temperature levels, exceeding by 20 percent those to which components shall be subjected to when in service, unless otherwise specified herein.

C. Equipment and Environment

1. CIH and Wayside Equipment

a. Equipment housed in rooms or wayside cases shall function in accordance with these Specifications and within a temperature range from -22 degrees F to +158 degrees F at relative humidity of 0 percent to 95 percent.

b. Equipment for use outside of instrument housing shall operate satisfactorily in weather conditions, including rain, snow, dirt, temperature variations and humidity variations, as determined by climatic conditions and from data published by the United States Government, National Oceanic and Atmospheric Administration for Boston and surrounding areas. In addition, follow recommendations of AREMA Signal Manual, Part 2.4.25 to minimize condensation and frost build-up.

2. Electrical Environment

a. Determine electrical environment to which signal equipment will be exposed. Provide a signal system and equipment that performs satisfactorily in a rapid transit environment of direct current propulsion power system.

b. The Contractor shall determine the electrical environment to which the signal electric/electronic equipment will be exposed and shall include in the design, safeguards to prevent interference from other systems affecting the system operation. Safeguards in the design shall be included to prevent interference generated by the system in affecting other systems or existing equipment.

c. It is the intent of the Authority to eliminate the use of all materials in confined areas which are combustible and which emit smoke and toxic fumes. Wherein products are defined without addressing the material and specifying with approval of the Engineer, the product shall be fabricated to address the flame, smoke, and toxic emission limitations.

d. All material designed, furnished, and installed by the Contractor shall be new and of the

highest quality and shall be fully compatible with signal systems presently in use on the Blue Line.

PART 3 - EXECUTION

3.01 GENERAL REQUIREMENTS.

A. The Contractor's final installation shall conform to the requirements as set forth in these Specifications and as shown on the Contract Drawings.

3.02 FINAL DESIGN REQUIREMENTS

A. The Contract Drawings are typical drawings. They depict the basic organization, structure, and logic sequence of the signal system operation. The typical drawings are provided to assist and guide the Contractor's final detailed design.

B. By their nature of being typical, the Contract Drawings shall not be construed to apply in every instance or condition encountered during the final detailed design. It is the Contractor's responsibility to provide full detailed design during the engineering phase of the Contract work.

C. Adjustments to the typical design shall be made by the Contractor to accommodate operating and structural conditions of the Blue Line as shown on the typical Contract Drawings and as specified herein. The final detailed design furnished by the Contractor shall be in accordance with recognized standards and practices used in the industry for a signal system that is modern, safe, reliable, easily maintainable and is fully compatible with the Blue Line signal system and operating conditions.

3.03 DESIGN CRITERIA

A. Fail-Safe Design Criteria

1. Component or system failures which are not self-detecting shall not cause unsafe conditions, even if added to other failures. Any number of simultaneous component or system failures attributable to the same cause or related causes shall not cause unsafe conditions. Any component or wire becoming grounded or any combination of such grounds shall not cause unsafe conditions.

2. Fail-safe equipment proposed for this Contract must be proved by minimum in-service operation of five years or shall be made available for type acceptance testing. If the Contractor has had this equipment in service for five or more years, he shall certify the installation dates and locations.

3. Type acceptance testing

   a. Type acceptance testing of components shall consist of bench tests on breadboard or prototype units as directed by the Engineer.

   b. Type acceptance testing of systems or subsystems shall consist of bench testing of operational systems or subsystems and/or field testing of same at the discretion of and as directed by the Engineer.

   c. All expenses incurred during type acceptance testing, except for expenses incurred by the Engineer, shall be borne by the Contractor.

4. All vital circuits shall be double-break, except within a signal instrument housing or wayside case

where only entering or leaving circuits are required to be double-break. When interface to the existing single-break circuit is required the Contractor shall provide relay contacts, cable terminals and cable conductors to accommodate future double break circuits.

5. All vital repeater relay circuits shall be designed on the cascade principle. The paralleling of repeater relays is not allowed.

6. Repeater contacts shall be assigned so that safety will not be compromised by the failure of any repeater relay to energize.

7. Contacts of each track relay shall only be used to control its first track repeater relay.

B. Tie-ins to Live Circuits.

1. The Contractor shall perform connection to and disconnection from live signal circuits including the necessary design, labor, materials, plans, engineering supervision and support required to interconnect signal equipment furnished, installed and relocated under this Contract with the existing Blue Line Automatic Block Signal System.

2. All work on the live signal system shall be performed by the Contractor in the presence of the Authority's forces.

3.04 CIRCUIT NOMENCLATURE

The Contractor shall follow the signal circuit nomenclature presently used on the Blue Line in order to maintain nomenclature consistency.

3.05 CONTRACTOR'S RESPONSIBILITY

A. The Contractor shall prepare and furnish all necessary temporary and final circuit drawings, detailed wiring and installation plans for the complete system including modifications to all existing as-built drawings impacted by the Contractor's work. The cable plans, including cable layout and cable breakdown for the final layout, are also to be included as part of the final drawings. The Contractor shall design and develop all wiring diagrams. Individual wiring diagrams shall be furnished for all equipment.

B. Any proposed change or corrections of the design arrangement shown on the Contract Drawings or on previously approved submittal drawings must be approved in writing by the Engineer before final detail plans are prepared and before manufacturing of the equipment.

3.06 INTERCONNECTIONS

A. Interconnection to the existing Blue Line signal system shall include, but not be limited to, modifications and tie-ins to the existing automatic block system and interlockings.

B. Wiring and Termination Requirements

1. Power feeders shall be segregated from other wiring.

2. All wiring other than power feeders and track circuit wires entering or leaving each enclosure shall be connected to terminals located on the entrance rack or terminal board with lightning and surge

protection.

3. Double post, test type terminals with two nuts and insulated connecting links shall be provided on entrance racks and terminal boards. These terminals shall permit the enclosure wiring to be isolated from the field wiring on an individual wire basis by backing-off a special counterbored gold plated test nut (gold nut) without removing the wires from their terminals.

4. Terminals for wires with 110 volts or higher voltage shall have protective (insulated) coverings.

5. Where "open link" connection is shown it shall be made by reversing counterbored (gold) nut over terminal connector.

6. Adjustments, Test Points, and Visual Indications

C. Unless approved by the Engineer, adjustable components shall be avoided wherever possible by the use of appropriate circuitry, stable components, and high-tolerance circuits. Adjustable components, useful during design development to experimentally determine the correct operational settings shall be eliminated in the final design. Adjustable components, where used after approval of the Engineer, shall have locking devices or shall be self-locking to prevent inadvertent operation and/or drift. Whenever practical, two or more points of adjustment which are required during the same tune-up operation shall be located within 12 inches of each other and in such a way that they can be operated by one man. Interacting adjustments will not be acceptable. The replacement of a component with a spare shall not require compensating adjustments to other components or modules.

PART 4 - MEASUREMENT AND PAYMENT

4.01 METHOD OF MEASUREMENTS

No separate measurement will be made for work required under this Section.

4.02 BASIS OF PAYMENT

All costs in connection therewith shall be included in the Contract Lump Sum Price for Signal and Communication System modifications.

4.03 PAYMENT ITEM

Item No.	Payment Item	Unit
1650.003	Signal and Communication System	LS

END OF SECTION

SECTION 16803

STAGING AND IMPLEMENTATION OF SIGNAL WORK

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the phasing of required installation, relocation, removal and protection in-place of signal equipment.

B. All costs related to the required coordination of work with the MBTA operations and maintenance, including development of schedules and attendance at meetings, shall be responsibility of the Contractor at no additional cost to the Authority.

C. All costs and delays to the Project because of the failure to coordinate work shall be responsibility of the Contractor.

1.02 QUALITY ASSURANCE

All the work specified herein shall be implemented in close coordination with of the Authority personnel.

1.03 SUBMITTALS

A. Within thirty days after notice to proceed, the Contractor shall submit to the Authority detailed staging and implementation plan. This staging and implementation plan shall include a schedule and sequence of signal work in coordination with other work performed under this Contract. This submittal shall contain all phases of signal work including, but not limited to, design, submittal for approval, furnishing, installation, testing and placing in service.

B. Before commencement of work, the Contractor shall submit for approval proposed material for and methods of protection of existing equipment.

PART 2 - PRODUCTS

2.01 MATERIALS

Materials and products required for the work to be performed under this Section are specified within the respective sections of these Specifications.

PART 3 – EXECUTION

3.01 SIGNAL SYSTEM MODIFICATIONS

A. Before beginning of demolition, all existing signal facilities shall be protected in place to avoid possible damage and to provide for continuous operation of the Blue Line.

B. When all or any part of work is ready for interface with existing operating signal system, the Contractor shall notify the Engineer thirty days in advance. All interface work shall be performed by the Contractor, and shall be closely coordinated with the Authority.

C. Prior to installation of equipment all temporary or permanent cables and individual wires shall be installed, tested and identified.

D. When existing signal facilities are worked upon, the Contractor shall have his Signal Engineer remain at the location to ensure proper system operation until receiving Authority acceptance for service.

E. The Contractor shall maintain a daily log of his activities on the Project and submit a copy to the Engineer on a weekly basis.

3.02 PROTECTION OF FACILITIES

A. The Contractor shall protect all temporary and permanent signal facilities to avoid any damage during construction as described in Section 01545 Protection of Work and Property and as specified herein.

B. The Contractor shall protect the existing track structure from damage, and shall protect the existing ballast from contamination.

C. The Contractor shall protect in place all existing signal facilities including housings, wayside equipment, cables and associated hardware. The Contractor shall note that signal facilities found within Project limits are integral part of the Blue Line Signal System.

D. No modifications to any element of the signal system to accommodate Contractor's activities will be allowed, except as specified herein or as directed by the Engineer.

E. The Contractor shall preclude any damage to existing facilities during demolition and construction. The Contractor shall design, submit for approval, furnish and install any structure required to protect signal equipment. The Contractor shall ensure that such protective structures do not interfere with train operations, display and visibility of signal aspects and normal functioning of all signal facilities.

F. In case of damage, the Contractor shall immediately notify the Engineer. Any equipment, cables and structures damaged during construction shall be replaced at once with identical material at no cost to the Authority.

G. Repair of damaged facilities or installation, testing and placing in service of replacement facilities shall be performed by the Authority's force account with assistance of the Contractor as directed by the Engineer. The Contractor shall be responsible for the cost of material and force account labor required to replace, test and place in service damaged facilities.

H. The Contractor shall be responsible for the cost of any interruption or delay to the train operations caused by the damage to the existing facilities including but not limited to the cost of manual block operations until full restoration of signal system.

I. The Contractor shall be required to remove and reinstall signal facilities if protection in place is not feasible. The Contractor shall develop and submit for approval detailed work procedure complete with description, schedule and applicable drawings. The Contractor shall be responsible for the cost of all material and labor, including force account activities.

J. Sixty days prior to placing in service any part of signal work the Contractor shall submit to the Authority for approval all circuits, wiring diagrams, detailed cable plans, conduit assignment, detailed installation layouts and applicable test procedures.

K. Prior to relocation of existing facilities the Contractor shall furnish, install and obtain approval of installation of all required mounting hardware, cable and other signal appurtenances.

3.03 CLEAN UP

A. The Contractor shall remove all protective materials from the signal equipment and dispose of that material off the Authority's property. All damaged equipment shall be replaced in-kind with new without time extension and at no additional cost and to the Authority. Any excavation shall be returned to suitable approved condition and original grade.

3.04 AS-BUILT DRAWINGS

A. Immediately after placing in service any part of signal work, the Contractor shall furnish to the Authority two sets of marked-up drawings with all as-installed modifications, including modifications to the existing circuit plans.

B. Within seven days after placing in service any part of signal work, the Contractor shall furnish to the Authority final as-built drawings for the completed work, including modifications to the existing circuit plans and wiring diagrams.

C. Prior to acceptance of the completed project by the Authority, the Contractor shall provide complete sets of all as-built drawings, as specified within Signal Drawings and Tracings Section of these Specifications.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16804

SIGNAL DRAWINGS AND TRACINGS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the production and furnishing of drawings and tracings and describes the general format of drawings, types of drawings, and the manner in which information shall be displayed. The Contractor shall provide the following:

1. Submittal (Shop) Drawings - Drawings displaying systems, subsystems, products, arrangements, layouts, etc. as designed by the Contractor and proposed for use in the installation of the Contract.

2. Working Drawings - Drawings that have been approved for use in the installation of the Contract.

3. As-Built Drawings – Drawings that show the actual installation of the Contract as approved and accepted. New as-built drawing tracings shall be provided for all work and including modifications to existing drawings. As-built drawings depicting modifications to existing circuits or equipment details shall show modifications without the use of "X" and "O" symbols.

B. All drawings shall be prepared in the latest release of the AutoCAD or as directed by the Engineer.

C. The effective date and identification number to be inscribed on the final tracings will be furnished by the Engineer prior to the time the tracings reach as-built condition and are ready for the Contractor's final processing.

D. The Contractor shall design the wiring diagrams and final circuit drawings for the equipment being furnished by him and also for any changes to the existing equipment as required by the Contract Documents. The Contractor shall be solely responsible for the correctness of the wiring diagrams and final circuit drawings including any drawings of existing circuits or equipment details that he reuses as part of a complete working system.

E. Circuit drawings shall contain circuit nomenclature, terminal identification, fuse and resistor sizes, relays with their contacts identified by number and by coordinates to identify the location of the relay on the instrument rack. Time settings of time relays shall be shown on the circuit plans beneath the corresponding time element relay symbol.

F. The Contractor shall prepare drawings showing the relay contact, relay location and detail wiring assignments for the final design. These arrangement drawings shall identify, by means of the manufacturer's reference number, the relay or component. These drawing shall also identify the contacts in use and show the circuit page where used.

G. The Contractor shall modify existing Blue Line Apparatus Tabulation sheets to include all equipment that he proposes to use under this Contract. The reference number that corresponds with Apparatus Tabulation shall identify all circuit elements and be inscribed on circuit and detail drawings.

1.02 TYPES OF DRAWINGS

The types of drawings to be provided shall include the following:

A. A Cover Sheet that shall bear the name of the submittal package and the name and location of the plan book in two inch high letters.

B. An Index Sheet that shall include the arrangement order and description of the plans. The relay coils that appear on the drawing shall be listed to the right of each drawing description.

C. Horizontal scale drawings showing the track configuration including the grade and curve profile and showing the location of pertinent items of signal system facilities such as signals, signal aspects and control lines, switch and lock movements, electric locks, instrument housings, junction boxes, stations, etc. The horizontal scale shall be 1" = 100'. The equality stationing shall normally be at the signals and shall be shown on the drawing. These drawings shall be known as Single Line Track and Control Line Plans.

D. Drawings, which indicate point-to-point cable runs and identify cable make-up and conductor wire size shall be known as Track and Cable Plans. These plans shall show the double line track configuration and identify each item of signal apparatus. These plans shall be identical to and shall match existing "as-built" plans in style and format.

E. Drawings showing the arrangement of terminal boards, instruments, or components in a room, bungalow, rack, instrument housing, junction box, cabinet or module shall be known as Detail Plans. The contact arrangement and both the working and spare contacts of vital and non-vital relays shall be shown on these plans along with information identifying the circuit pages where they are used..

F. Drawings on which detailed information is shown for the mechanical installation of signal equipment, such as signals, switch and lock movements, electric locks, train stop layouts, etc. shall be known as Installation Layout Plans.

G. Drawings showing complete printed circuit board layouts, component listing and circuits, shall be known as Printed Circuit Board (PCB) Drawings.

H. Drawings showing the dimensions and internal mechanical and electrical details of particular pieces of equipment or assemblies shall be known as Product Drawings, but shall bear the title of the particular piece or type of equipment shown.

I. Drawings showing the various types of control, operating and indication circuits required, shall bear the title of the particular function(s) performed by the circuits illustrated and shall all be classified as Circuit Drawings. These plans shall also match to the existing "as-built" plan set in style and format.

J. Schematic drawings of various energy distribution systems or subsystems that may be required shall be known as Power Distribution Plans. These schematics may be included as part of the Circuit Drawings.

K. Drawings showing temporary work required, but which will not remain as a part of the completed work shall be known as Temporary Plans and shall be entitled to define the purpose served.

L. Drawings showing the details of electrical connections for various pieces of signal system equipment shall bear the title of the particular piece of equipment, but shall all be classified as Wiring Diagrams.

M. Drawings that indicate cable routing and identify cable make-up and conductor wire size shall be known as Cable Routing Drawings. These drawings, when depicting interior cable routings within buildings, shall show building floor plans, identify conduit, duct or raceway locations and shall indicated the required sizes of all such conduit, duct work, and cables.

N. Drawings showing the location of the conduit ends installed for cable runs beneath walkways, tracks, and through ductlines, concrete, and other obstacles and as shown on the Contract Drawings shall be known as Conduit Routing Plans.

O. Track Circuit Plans shall have a double line track layout drawn at the top of the plan showing the equipment, polarities, relay and battery ends, solid state track circuit locations etc. within interlockings, crossings, wayside signal and similar locations. The bottom of the plan shall show the track circuit logic. These plans shall also match to the existing "as-built" plan set in style and format

P. Drawings showing the software logic-sequence of vital and non-vital processors shall be known as Flow Diagrams. These drawings shall bear the title of the particular function(s) performed by the logic illustrated. Whenever Flow Diagrams are part of the work, the Contractor shall also provide drawings showing the equivalent circuitry in relay logic format.

1.03 QUALITY ASSURANCE

A. The Contractor shall check drawings and final tracings for both form and content prior to submittal. Points to be checked shall include the following:

1. Conformance to the Specifications
2. Compliance with the existing MBTA as-built drawing format
3. Logical grouping and arrangement of subject matter
4. Accuracy
5. Legibility
6. Neatness
7. Line Quality
8. Lettering Quality
9. Reproduction Quality

B. Approval of drawings and tracings shall be at the discretion of the Engineer. The Engineer will consider the same points enumerated above, with the basic criteria for obtaining approval being that drawings are easy to read, understand and use.

1.04 SUBMITTALS

A. When submitting drawings to the Engineer for the initial approval of a product, subsystem, or location, the Contractor shall submit all drawings germane to the subject at one time. This logical grouping of drawings, sufficient to completely cover the subject concerned, shall be known as a Submittal Package. All submitted drawings shall be prepared in accordance with these Specifications and shall be considered a prototype of as-built drawings.

B. The Contractor shall submit one reproducible and five legible copies of all shop drawings and working drawings to the Engineer for approval. These drawings shall be complete and detailed and shall include, but not be limited to, the following:

1. Single Line Track and Control Line Plans
2. Double Line Track and Cable Plans
3. Detail Plans
4. Product Drawings
5. Installation Layout Plans
6. Cable Routing Plans
7. Circuit Drawings
8. Flow Diagrams
9. Energy Distribution Schematics
10. Wiring Diagrams
11. System Drawings
12. Material Lists
13. Apparatus Tabulation

C. The Contractor shall furnish five sets of prints of circuit drawings, wiring diagrams, and cable plans marked "O-ed line = IN" and "X-ed line = OUT" to show his design changes to existing signal and communication facilities. Submittal shall be made sixty days prior to making the changes and placing them in service.

D. The Contractor shall also furnish five sets of prints of circuit drawings and wiring diagrams marked "O-ed line = IN" and "X-ed line = OUT" to show temporary work. This temporary work shall include work required during the stages of placing portions of the work in service. The prints shall be furnished at least sixty days prior to making the changes and placing in service.

E. One set of full size tracings and five sets of half-size reproducible copies of the As-Built Drawings shall be submitted no later than thirty days after placing any portion of the work shown on the approved plans into service.

F. The Contractor shall submit samples of the final inked drawings for approval by the Engineer within ninety days after receipt of a notice-to-proceed.

PART 2 - PRODUCTS

2.01 MATERIAL

A. The tracings for the final As-Built Drawings shall be drawn with India ink on four-mil-thick double matte mylar film, or printed on four-mil-thick double matte mylar by automated techniques (CADD) as approved by the Engineer. The materials and methods used to produce these tracings shall result in tracings that are easy to revise without damage to the tracing.

B. Electronic file copies of tracings shall also be provided. File format shall be the latest AutoCAD release (.DWG file) or a universal file transfer format (.DXF file). Electronic file media shall be Compact Disk (CD) and shall be approved by the Engineer.

C. The aperture card reproductions (three sets) of the final As-Built drawings shall be provided in accordance with the following specifications:

1. Negative: Type 1D, Single Silver

2. Size: 35 mm 30 x reduction per Reduction Ratio Guide, Department of Defense Specification MIL-STD-9868D.

3. Method: Production practices as described in National Micrographics Association (NMA) NS-104".

D. Printed book of the final as-built drawings (five sets)

PART 3 - EXECUTION

3.01 BOOKS OF DRAWINGS

A. The Contractor shall supply books of specific signal system drawings for submittal packages and plan books as specified herein. The name of the submittal package and the name and location of the plan book shall be printed on the cover sheet in two-inch high letters. These books of drawings shall be assembled in a logical order and shall consist of, but not be limited to, the following components:

1. Index sheet of the same size as the drawings.
2. Symbol sheet.
3. Material reference sheet.
4. Protective cover and backing sheets.
5. A device for binding the left-hand edges of the drawings firmly, but in such a manner that drawings may be open flat, easily added, removed, or replaced without damage to the drawings.

3.02 BASIC FORMAT REQUIREMENTS FOR DRAWINGS

A. Each drawing shall be prepared on tracings of the standard size adopted by the MBTA for Blue Line rapid transit signal system design.

B. R size (24" x 42") or C size (21" x 42") may be used for such drawings which cannot be accommodated on other sizes, as approved by the Engineer.

C. Drawings shall not be crowded or cluttered, but shall be arranged to be easily readable. Circuitry shall be presented on the drawing with a minimum of crossed or offset lines.

D. New drawings requiring continuation of, or matchlines to, existing drawings shall match the existing drawings in format, relative placement of equipment, cables, tracks, and other items depicted on the drawings.

E. Complete circuits shall be shown on each drawing insofar as possible. A minimum of circuit continuations shall be used. When continuations are used they shall be clear and specific and shall include the identity of circuit and continuation sheet.

F. Local circuits shall be drawn with relay coils, timers, motors, or other operated devices shown near the right or left border of the drawing wherever practical. Where there is a choice the right border shall be favored. Contacts in circuits shall be laid out in geographical succession insofar as possible and practical. Relay contacts shall be lined up one below the other insofar as practicable.

G. Line circuits shall be arranged with West to the left, to geographically match the track layout. On line circuit plans, only line circuits shall appear on the right and left sides of the drawing. Circuits between two or more locations shall be shown on one page, insofar as possible and that page shall be incorporated into the plan book for all locations included.

H. Relay nomenclature shall be printed in two lines, as follows:

Top - Name Identification: 2L 3
Bottom - Function Description: ASR NWCPR

I. Relay nomenclature shall appear above top of coil or contact.

J. Stick contacts shall line up under the coil of the controlling relay. Relay contacts shall line up with the controlling coil and other contacts of the same relay insofar as practicable. Different relay contacts and coils shall not line up.

K. A minimum distance of 0.40 inch shall be maintained between lines representing circuit wiring. Nomenclature shall be sized such that the reduced size plan books for CIHs, and cases shall show a text size of 0.075 inches minimum. All spacing shall be in multiples of tenths of inches.

L. All track and signal plans shall show the survey station for all signals, interlocked switches, track cut sections, switch locks, signal instrument housings and all other signal related equipment.

M. Circuits shall not be drawn as schematics, but shall be drawn to reflect the actual wiring of the circuits.

N. The arrangement of circuitry shall be in such a manner that no more than two wires shall be shown connected to a single terminal or contact pin. A uniform method shall be used to indicate the actual location of double wire connections when it is not desirable to show both wires at the point of termination.

O. Circuit drawings shall provide sufficient information by means of contact and terminal numbering to easily enable the tracing and testing of such circuits.

P. The Contractor shall use AAR standard symbols and nomenclature, except where they are at variance from the symbols used on existing as-built drawings.

Q. When the final circuit is not wired as shown on the Contractor's drawing, the Contractor shall revise his tracing to indicate the actual wiring before final as-built prints are made.

R. Detail drawing such as rack arrangement plans shall, in addition to wiring terminal assignments, provide material reference number information for the equipment and components being used. These drawings shall also show the circuit page number where every relay coil and "in-use" contact may be found.

3.03 BOOKS OF PLANS

A. The Contractor shall provide five sets of two books of approved drawings for the signal system. These books must be available to the Engineer and on the job site, three weeks prior to start of the installation and testing activities.

1. One plan book shall consist of all the circuit drawings and shall include applicable prints from adjacent cases to show tie-ins.

2. The second plan book shall consist of detail drawings and arrangement or internal layout plans and wiring diagrams for the various pieces of equipment.

B. Individual circuit and detail plans of each CIH, case, and other instrument housing shall be provided in a plan book format and shall be furnished for each house or inserted in the door pocket of each case. The final size of this plan book shall be 11 inches by 17 inches.

C. These books and plans shall be updated immediately to reflect any changes made in the circuits or equipment.

D. The Contractor shall maintain an additional complete set of up-to-date plan books for this Contract at his on-site headquarters.

3.04 FINAL AS-BUILT DRAWINGS

The Contractor shall provide the final As-Built drawings, as described herein, prior to final acceptance by the Engineer.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16808

EXTERNAL SIGNAL AND COMMUNICATIONS CABLE

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing and installing of various types of cable required for signal, communications and signal power system external to wayside housings, cases, factory wired mechanisms, and buildings.

B. Material and workmanship shall be of the highest quality assuring durability for minimum life expectancy of forty years. These cables shall be suitable for use in the environment to be encountered and shall be certified for continuous operation at 75 degrees C in wet or dry locations with no conductor failing in continuity or with loss of insulation to cross or ground less than one meg-ohm.

C. Multi-conductor main cable containing more than two conductors shall contain a minimum of 20 percent spare conductors or two spare conductors, whichever is greater. Local distribution cable shall contain a minimum of ten percent spare conductors or one spare conductor, whichever is greater, except that two conductor cables will not require spare conductors.

D. Express cables shall be defined as those cables which run between housings, or those cables containing conductors for more than one system function. Local distribution cables shall be defined as those cables run between a housing and an individual unit of equipment.

E. The wire and cable to be furnished under this Contract shall meet the requirements of the designated Authority wire and cable specifications as referenced herein.

F. The standard underground and aerial cable make-ups shall be as listed in the Technical Appendix of these Specifications, unless otherwise specified herein.

1.02 QUALITY ASSURANCE

A. Pre-qualification

1. All cable manufacturers supplying cable for this Contract must be pre-qualified by the Engineer. The Contractor shall provide all of the data required for the Engineer's evaluation and shall make the arrangements for any required demonstrations and tests.

2. Qualifications shall be based on the following criteria:

a. Past Performance and Experience. The cable manufacturer(s) must demonstrate previous successful experience in supplying cable to the railway or transit industry for use as vital signal control and communication cables. A list of such installations shall be provided for each cable manufacturer to be considered.

b. Quality Assurance Program. The Manufacture of cables in accordance with the requirements of this Specification shall be accomplished in compliance with a Quality Assurance Program that meets the intent of the ASQC Standard CI-1968; General Requirements for a Quality Program. Such compliance shall promote a thoroughly tested cable which will render long service life to the user. Prime concern must be focused on the necessary formal assurance requirements to insure that cable failure cannot be attributed to actions or lack of actions by the manufacturer.

c. Technical Data. The Contractor shall provide full technical data which demonstrates compliance with the requirements of this Specification for each specified cable type the Contractor plans to supply.

d. Demonstration Tests. The Contractor shall make arrangements with the prospective cable manufacturer(s) to perform demonstration tests as required by the Engineer.

e. Sample Specimens. The Contractor shall, if requested by the Authority, furnish to the Engineer within twenty (20) days after the close of bid date, sample specimens in four foot lengths similar to that which the Manufacturer proposes to furnish for each type cable specified herein. The sample specimens shall remain the property of the Authority.

f. The Manufacturer shall certify that he shall comply with the following warranty prior to selection:

(1) The Manufacturer warrants that the design, material and workmanship incorporated in each item of cable shall be of the highest grade and consistent with the established and generally accepted standards for aerial and underground cable for vital railroad signal, communication, and power circuits; and that each such item and every part and component thereof shall comply with this Specification.

(2) The Manufacturer agrees that this warranty shall commence with the acceptance of each item of the cable, whether the defect be patent or latent, and shall for a period of two years after initial satisfactory operation of the item or four years after acceptance of the item, whichever is shorter.

(3) The warranty covering any length of cable that shall be replaced by the Manufacturer under the above conditions shall be reinstated for a period of two years effective as of the day when said replacement is effected. If the failure is found to be of major importance and affects any other item of cable, the reinstatement of the warranty shall then be extended to cover the item so affected as well, and shall start as of the date of such replacement. The warranty reinstatement provided for in this subparagraph (3) shall apply only to the first replacement or repair of any such item and, in the case of failure of major importance, to the first extension of the said warranty to said affected items.

(4) The foregoing warranties are exclusive and in lieu of all other warranties, written, oral, implied or statutory (except as to title and freedom from lien). In no event shall the Manufacturer be liable by reason of breach of warranty for special or consequential damages.

B. After Selection

1. The Contractor shall monitor the manufacturer of the wire and cable to ensure that the approved Quality Assurance Program is being closely adhered to and that the wire and cable is being manufactured in accordance with this Specification and the approved submittals.

2. Each finished wire and cable shall be traceable to the test date on file for each step in its manufacturing process.

3. Inspection

   a. The Authority or its authorized representative shall have the right to make such inspection and tests as necessary to determine if the cable meets the requirements of this Specification. The inspector for the Authority shall have the right to reject cable which is defective in any respect.

   b. The Authority shall be given thirty days advance notice of the date the cable will be ready for final testing so that the Authority may witness the tests, if it so elects.

   c. Physical tests shall be made on samples selected at random at the place of production. Each test sample shall be taken from the accessible end of different reels. Each reel selected and the corresponding sample shall be identified. The number and lengths of samples shall be as specified under the individual tests. All applicable tests for the cable materials and cable construction specified shall be performed.

   d. The Manufacturer shall provide, at the point of production, apparatus and labor for making any or all of the following tests under the supervision of the Authority's inspector; to include:

      (1) Conductor size and physical characteristics.
      (2) Insulation high voltage and insulation resistance tests.
      (3) Physical Dimension Tests.
      (4) Special Tests on Materials in Coverings.
      (5) Final high voltage, insulation resistance, and conductor resistance tests on shipping reels.

   e. Certified electrical and physical test reports shall be furnished for the finished multiple conductor cables prior to the time of shipment. Each test document shall, in addition to the test results, indicate the date the tests were performed and the signature of the Manufacturer's authorized representative.

   f. The Authority reserves the right to conduct itself, or by its duly authorized representative, those tests it so elects to further satisfy itself that the cable is manufactured in accordance with the requirements of this Specification.

1.03 SUBMITTALS

A. The Contractor shall submit the following to the Engineer for approval:

1. List of each cable manufacturer's railway signal installations;
2. Each cable manufacturer's Quality Assurance Program;
3. Full technical data for each type of cable which each cable manufacturer intends to supply;
4. Aerial cable attachments details;
5. Method of cable entrance into the instrument housing;
6. Cable installation details at raceway transition;
7. Cable conduit layout and for permanent and temporary installation;
8. Aerial cable support messenger attachment details;
9. Messenger wire and load calculations;
10. Type and method of splicing.

B. The Contractor shall submit two certified copies of the following to the Engineer for approval:

1. Cable test reports for all demonstration tests required by the Engineer;
2. Cable test and inspection reports for tests and inspections required and described by these Specifications;
3. Test reports of cable tests conducted in the field in accordance with approved testing procedures;
4. Certification that each cable supplied complies with the requirements of these Specifications.

C. Information to be supplied by certified cable test reports shall include the following:

1. Report number;
2. Date and location of test;
3. Description of test and test conditions;
4. Complete cable or wire description;
5. Lot, batch, or reel identification number;
6. Quantitative test results;
7. Summary of the test results;
8. Information on the components of the cable tested to include batch numbers and physical and electrical properties.

D. The Contractor shall submit a complete, signed and notarized standard Wire and Cable Test Report Sheet as part of each cable test report. This form shall be as represented by the sample form contained within Technical Appendix of this Specification.

E. The Contractor shall furnish to the Authority product data cut-sheets and a sample specimen of a four foot length, if required, for each proposed cable type. The samples shall remain the property of the Authority.

F. The Contractor shall furnish to the Authority five copies of the cable manufacturer's instructions and procedures together with one sample end seal specimen for potheading of each type underground cable to be furnished and installed under this Contract.

G. The Contractor shall submit, prior to construction, detail plans of any cable duct line installations showing all hardware to be used, methods of attachment, cable routing through manholes, and fill.

1.04 SPLICING - SIGNAL POWER & COMMUNICATIONS CABLES

A. The insulation, together with materials supplied for splicing the cables and their individual conductors shall be such as to make dependable moisture-proof splices able to withstand the environment comparable to and for the same life expectancy as the original unspliced cable.

B. The manufacturer shall supply not less than six copies of instructions for splicing. The instructions shall be forwarded with the certified test results for each reel of cable. The instructions shall specify the exact nature of splicing materials to be employed, and the manner in which they are to be applied to include preparation of the cable sheath and individual cable conductors.

C. The manufacturer shall, as mutually agreed as to time and place, provide a qualified individual to demonstrate to the Authority's representative the recommended and appropriate techniques for splicing cables.

D. No splices will be allowed in vital or non-vital signal cables.

1.05 EXISTING COMMUNICATIONS CABLE

A. All existing communications cabling shall be protected in place during full duration of Construction Phasing.

1.06 DELIVERY, STORAGE AND HANDLING

A Shipping, storage, and handling shall be in accordance with AREMA Signal Manual, Part 10.4.1 and Part 10.3.16, Paragraphs 20 and 21. During storage and handling, prior to final conductor termination, cable ends shall be sealed to prevent the entrance of moisture. Delivery, storage, and handling shall be in accordance with the MBTA Standard Specifications.

PART 2 - PRODUCTS

2.01 CABLE SPECIFICATIONS

A. Signal and Communications Cables

The signal and communications cables (underground and aerial) including 100 and 12 pair #19 AWG and 25 pair and 4 pair 22 AWG telephone cable to be furnished under this Contract shall meet the requirements of the MBTA standard cable specifications contained within the Technical Appendix of these Specifications.

B. Low Voltage Power Cables (less than 1000 volts)

Low voltage power cables shall be Type RHH or RHW, intended for use as direct burial, in raceways or aerial applications. Conductors shall be stranded copper per ASTM B-3 or B-8. Insulation shall be cross-linked polyethylene, rated for 600 volts, in accordance with NEMA WC 7/ICEA S-66-524.

C. Fiber Optic Cable

See Section 16749 of these Specifications for fiber optic cable to be furnished under this Contract.

2.02 MESSENGER WIRE

A. The Contractor shall perform all messenger loading calculations. Messenger wire shall be a copper-coated steel strand, EHS grade. The copper clad wire shall be not less then 3/8-inch, 30 percent HS-7W as approved by the Engineer. Stranding shall consist of minimum seven strands, each strand being a No. 8 AWG bare copper covered steel wire. The copper shall be applied to each of the steel cores by the molten welding process, and shall be free from all surface imperfections. The finished copper covered steel messenger wire shall have a breaking strength of not less than 10,000 pounds.

PART 3 - EXECUTION

3.01 CABLE INSTALLATION

A. General

1. The installation of wire and cable shall conform to Part 10.4.40 and Part 10.4.1 of the AREMA Signal Manual, except as modified herein.

2. The Contractor shall give the Engineer 24 hours notice prior to installing cables.

3. The Contractor shall provide sufficient slack in cable conductors at all terminating posts to enable three re-terminations of the conductor due to broken eyelets without re-servicing or re-potheading the cable.

4. In certain types of installation, the cable cannot be constrained; therefore, ample cable slack shall be provided for additional flexibility due to vibration of such equipment.

5. Cables shall not be bent to a radius less than 10 times the diameter of the cable during installation as finally installed.

6. All signal cable runs shall be continuous without splices between cable terminating locations.

7. Tags to identify cables shall be of plastic material. Tags shall be lettered to correspond with the cable destination and number of conductors in the cable. The type of tag to be used shall be as described within Miscellaneous Components and Products section of these Specifications.

8. All cables shall be terminated in conductor order. Individual cable conductors shall be identified at each cable termination with plastic tags as specified within Miscellaneous Components and Products section of these Specifications. All spare conductors in each cable shall be terminated and identified.

9. All cable entrance openings in equipment enclosures and junction boxes shall be sealed with either a compression type fitting or pliable sealing compound after the cable is in place. Sealing compound shall be used to seal the area around cable where the cable emerges from the end of a conduit, pipe, or duct bank. All spare conduits shall be sealed or plugged in an approved manner.

10. An approved lubricating medium, non-injurious to the cable insulation, shall be used when pulling

cables into conduit, pipe, or duct bank.

11. Where cable transfers from trays or troughs to conduit the ends of the conduit shall be fitted with plastic end bells to prevent damage to the cable.

12. Wherever multiple conductor cables are terminated the outer sheath of the cable shall be carefully removed to the point of cable entrance. At the end of the cable sheath or covering, two layers of plastic electrical tape shall be applied.

13. Cable carrying 120V or more rated circuits shall be installed in the separate trench, conduit, trough, messenger or other raceway separated from signal cable, except as otherwise provided for herein.

B. Non-Buried Installation

1. Installation in Trays or Troughs

a. Cable installed in trays or troughs shall be laid therein and not pulled in place. Cables installed in trays and troughs shall have a minimum amount of crossover and shall not be pulled tightly around bends.

b. Cable tray openings through walls, including the tunnel walls, shall be made by the Contractor. After installation of the new trays and cables, the openings shall be grouted and sealed to provide a fire-rated installation.

2. Installation in Conduit or Pipe

Cables shall not cross one another when they are pulled into a conduit or pipe and care shall be taken not to have the conductors pulled tight or kink in conduit fittings or boxes. All cables to be installed in a conduit or pipe shall be pulled and installed simultaneously and not exceed a fill ratio of 40%.

3. Aerial Cable Installation

a. Runs of messenger wire for support of signal and communications wire and cable shall be furnished and installed by the Contractor as required. The Contractor shall perform all messenger loading calculations. For purposes of determining loading requirements five pairs are to be taken as the equivalent of one conductor. Similarly, each No. 8 AWG wire is to be considered equivalent to two conductors and each No. 6 AWG wire or larger as four conductors. The Contractor shall be responsible for determining the exact quantity of messenger wire that will be required.

b. Messenger wire shall be dead-ended using turnbuckles and strand vises. All ferrous messenger support hardware shall be hot dipped galvanized. Down guys with earth anchors shall be provided at messenger and cable dead-ends.

c. A cable bundle supported by a single messenger shall not exceed six inches in diameter. Wherever cables to be installed on messenger would make a bundle exceeding six inches in diameter, the Contractor shall provide additional messenger as approved by the Engineer.

d. The radius of cable bends for insulated cable shall be not less than ten times the diameter of

the cable. The radius of cable bends for communication cable shall not be less than fifteen times the diameter of the cable. For flat twin conductor cable, the diameter over the major axis shall be used.

e. Where cables leave the messenger to enter cases, conduits or other equipment, the cable shall be wrapped with nylon filament rope to protect the insulation as approved by the Engineer. The wire and cable shall be tied to new messenger in two steps as follows:

(1) Temporary tying, which consists of tying the cable close to the messenger by means of temporary marline or rope ties, shall be placed sufficiently close together to hold the cable to the messenger without undue sagging of slack. Round metal "S" hooks may also be used to support the cables during forming of the bundle before permanent tying or strapping.
(2) The permanent tying, shall be done with approved cable straps and nylon ties.

f. Wire and cable shall be fastened to the messenger wire by means of cable straps, as approved by the Engineer. Straps shall conform to the existing Blue Line straps to provide ease of maintenance. The maximum distance between straps shall be fifteen inches, with additional straps provided to meet special conditions. Strain relief shall be furnished and installed at all points where cables leave the messenger to enter terminal or instrument housing, or any other raceway or equipment, or as required by the Engineer. Cables shall be securely fastened and anchored to the messenger by extra wrappings of nylon filament rope to prevent cable from slipping or sagging,

4. Cable Transition Areas

Where signal cable runs change from one type of installation to another type the Contractor shall furnish and install transitional enclosed raceway. The Contractor shall submit his proposed method of raceway transition for approval by the Engineer.

D. Special Protection

The Contractor shall provide appropriate special protection for cables in areas where the cables are unavoidably exposed to hazardous conditions such as vibration or sharp corners on equipment. The Contractor shall be responsible for replacing, at no additional cost to the Authority, any cable he has installed which is subsequently damaged prior to acceptance as a result of his failure to provide such special protection.

3.02 TESTS

All installed external cable shall be tested in accordance with requirements of Signal System Tests Section of these Specifications.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16817

SIGNAL LAYOUTS

PART 1 - GENERAL

1.01 DESCRIPTION

This Section specifies relocating existing color light type signal layout for automatic signal location, pantograph detection signals and "T" signal for grade time section. A symbol form shown on the Contract Drawings is used to indicate the approximate locations where signal layouts are required.

1.02 QUALITY ASSURANCE

A. The Contractor shall inspect and test each signal layout prior to relocation. The Contractor shall ensure that signal unit is in good working condition and meet the requirements of AREMA Signal Manual, Part 7.1.1.

B. The Contractor shall inspect each signal layout after it has been installed at new location. This inspection shall conform to the Contractor's Installation Inspection Procedure as approved by the Engineer. Installation will not be considered complete until the Contractor has corrected all installation defects to the satisfaction of the Engineer.

C. The final operating tests to determine the acceptability of each complete signal layout shall be performed as described within the Signal System Tests Section of these Specifications.

D. Existing signal layout in the areas of construction shall be protected in place for the duration of construction. Any signal layout or parts thereof damaged during construction shall be replaced at no additional cost or time delay to the Authority.

1.03 SUBMITTALS

A. The Contractor shall submit site-specific installation layout, mounting details and installation dimensions for each required signal location.

B. The Contractor shall submit an Installation Inspection Procedure for each type of signal layouts prior to installation.

PART 2 - PRODUCTS

2.01. MATERIALS

A. Existing signal units to be relocated are transit type color light signals manufactured by U.S. & S. Co.'s (formerly by Transcontrol). The Contractor shall furnish and install all new mounting hardware required for installation of signals at new location.

B. Signal Number and Speed Plates

C. The Contractor shall furnish and install new signal number plates for each relocated signal and "T" signal for timed section. Signal plates shall be made out of enameled sheet steel. The enamel shall be baked on the sheet steel in such a manner as to ensure that every part of the metal has a smooth, durable, and permanent covering, free of any imperfections.

D. All signal plates shall have black synthetic enamel lettering on a white reflex reflecting background.

E. The signal plate shall be bracket mounted under the lowest signal lens in the assembly and shall be fastened by four brass screws, with lead and brass washers under the screw heads and under the enameled plate. The lead washers shall be installed adjacent to the enamel.

F. Each number plate shall meet the requirements of AREMA Signal Manual, Part 14.6.1 where the requirements of the AREMA Specifications do not conflict with the requirements established in this Section.

G. All mounting hardware shall meet requirements as specified within the Miscellaneous Components and Products Section of these Specifications.

PART 3 - EXECUTION

3.01 INSTALLATION

A. All signal layouts shall be relocated in accordance with Contract Drawings and with installation drawings approved by the Engineer. The exact final location shall be determined from field measurements, and shall be approved by the Engineer.

B. Each signal lens configuration must be distinct and unmistakable when viewed from a height of 7 feet above the top of rails at a minimum distance of 600 feet. The Contractor shall furnish all labor, equipment, and material, including shims or special tools, required to properly focus and align the signals both horizontally and vertically in order to obtain specified sighting distance.

C. Lamp voltage shall be set at 10 volts plus or minus 10 percent at the signal unit. Lamp voltage settings for pantograph detection signal units shall be as required by the detection system's operating requirements.

D. The Contractor shall paint each signal layout with one primer coat of rust preventive paint and one finish coat of paint. The finish coat of paint for the exterior of the lamp compartment housing shall be dull (non-reflective) black. One coat of paint shall be applied after installation and prior to placing in service. The paint shall be of the same quality and texture as the manufacturers finish coat.

3.02 FIELD TESTS

A. Tests for proper operation and setting of lamp operating voltages shall be made in accordance with the Signal System Tests Section of these Specifications for signal layouts.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16819

POWER FREQUENCY TRACK CIRCUITS

PART 1 - GENERAL

1.01 DESCRIPTION

This Section specifies relocation of existing 60 hertz AC track circuits based on two element vane-type induction relays for train detection as shown on the Contract Drawings.

1.02 QUALITY ASSURANCE

Before relocation of track circuits, the Contractor shall perform preliminary tests in accordance with approved test procedures to ensure that track circuits are operating in accordance with these specifications. Any deviation shall be reported in writing to the Engineer. After relocation track circuits shall be tested and test results approved by the Engineer before placing track circuits in service. Test results prior to and after relocation shall be the same.

1.03 SUBMITTALS

The Contractor shall submit installation and test procedures, including test results data sheets.

PART 2 - PRODUCTS

PART 3 - EXECUTION

3.01 INSTALLATION

A. Power frequency track circuits shall be installed at locations indicated on the Contract Drawings and in a manner as shown on the approved installation plans and as described within the approved installation procedure.

B. Installation and adjustment shall be made in accordance with the approved installation procedure.

3.02 TESTS

Tests shall be made in accordance with the approved test procedure and in accordance with the requirements of the Signal System Tests Section of these Specifications.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16823

IMPEDANCE BOND LAYOUTS

PART 1 - GENERAL

1.01 DESCRIPTION

This Section specifies relocation of existing impedance bond layouts. A symbol form shown on the Contract Drawings is used to indicate the approximate locations where impedance bonds are required..

1.02 QUALITY ASSURANCE

The Contractor shall inspect and test each impedance bond prior to relocation. The Contractor shall ensure that impedance bonds are in good working condition and meet the requirements of AREMA Signal Manual Part 8.4.5 where these requirements do not conflict with any requirement specified within these Specifications.

Existing impedance bond layouts in the areas of construction shall be protected in place for the duration of construction. Any impedance bond or parts thereof damaged during construction shall be replaced at no additional cost or time delay to the Authority.

1.03 SUBMITTALS

The Contractor shall submit the following to the Engineer for approval:

1. Site specific impedance bonds installation drawings showing physical dimensions of bonds and all elements comprising the layout.

2. Installation inspection and bonds test procedures.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Existing impedance bonds are rated to carry 2500 amperes per rail continuously and manufactured by U.S. & S. Co.'s (formerly by Transcontrol). The Contractor shall furnish and install all new mounting hardware required for mounting the impedance bonds at the new location.

B. Cables for neutral connections between the bonds, connection of the bonds to the rails, and connection of neutrals for equipment shall be furnished and installed in accordance with the External Signal Cable Section of these Specifications. Exothermic connections to the rails shall be in accordance with the Running Rail Bonding Section of these Specifications.

PART 3 - EXECUTION

3.01 INSTALLATION

A. All impedance bonds shall be relocated in accordance with Contract Drawings and with installation drawings approved by the Engineer.

B. The exact final location shall be determined from field measurements, and shall be approved by the Engineer.

C. The Contractor shall furnish and install new crossties for the support of the impedance bonds, and shall relocate and space crossties at locations where impedance bonds are removed and at locations where bonds are to be installed in accordance with the approved installation drawings.

D. The Contractor shall retamp and redress the ballast in the area of the new and respaced crossties. The Contractor shall repair damage to the track structure and shall adjust the track line and level in the area of the respaced ties so that the track structure will meet the existing track tolerances.

E. With the wooden ties in place and properly tamped, the Contractor shall install impedance bonds as shown on the approved installation drawings.

F. The impedance bond shall be center-mounted on the ties and shall be so mounted that the top of the impedance bond shall be at least one-half inch below the plane of the top of the rails.

G. Impedance bonds and trackside tuning units, when required, shall be shock-mounted to effectively isolate them from the shock and vibration normally encountered in the area in which they are mounted.

H. Impedance bonds located between the rails shall be protected against dragging equipment in both directions by steel ramps.

3.02 TESTS

A. The Contractor shall test the impedance bond as per the approved installation test procedure as specified within the Signal System Tests Section of these Specifications.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16824

AUTOMATIC TRAIN STOP LAYOUTS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies relocation of existing train stop layouts. A symbol form shown on the Contract Drawings is used to indicate the approximate locations where train stop layouts are required. The Contractor shall furnish and install all new mounting hardware required for mounting train stop layouts at the new location.

B. The work to be done under this Section also consists of relocating of the manual key-by releasing push buttons.

1.02 QUALITY ASSURANCE

A. Train stop shall be tested prior to relocation. The Contractor shall ensure that the unit is in good working condition and meet the requirements of these Specifications.

B. Train stop shall be tested immediately after it has been installed and any deficiencies noted shall be corrected. This inspection shall be conducted in conformance with the requirements of the Contractor's Inspection Procedure as approved by the Engineer.

C. The final operational tests of the automatic train stop shall be conducted as described in Signal System Tests Section of these Specifications.

D. Existing train stops in the area of construction shall be protected in place for the duration of construction. Any train stop or parts thereof damaged during construction shall be replaced at no additional cost or time delay to the Authority.

1.03 SUBMITTALS

The Contractor shall submit the following to the Engineer for approval:

1. A site specific installation drawing of automatic train stop layout showing physical dimensions of all elements comprising the layout.

2. A diagrammatic drawing of the test gauge proposed for installing and aligning the trip arms.

3. The Contractor shall submit an Installation Inspection and Test Procedure prior to installation of the train stop.

PART 2 - PRODUCTS

2.01 AUTOMATIC TRAIN STOP

A. Existing Automatic train stop to be relocated is a Union Switch & Signal Company, Model EM-1 with right and left tripper arms and hook down brackets.

B. The Contractor shall furnish and install all new mounting hardware required for mounting the impedance bonds at the new location including new crossties.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Automatic train stop layouts shall be installed at the new location as shown on the Contract Drawings. The exact final location shall be determined from field measurements, and shall be approved by the Engineer.

B. Location of the train stop mechanism with respect to the top of rail and to the running rails shall be in accordance with the approved installation drawings.

C. Adjustments shall be made to provide clearance for the stop arm bearing assembly and to maintain the required vertical distance between each stop arm and the top of rail.

D. Respacing of ties and any other work necessary to install the layout shall be in accordance with the approved installation drawings and shall be part of the work. The Contractor shall install new crossties for mounting automatic train stop layouts. The Contractor shall retamp and redress the ballast in the area of new and respaced crossties. The Contractor shall repair damage to the track structure and shall adjust the track line and level in the area of the replaced ties, so that the track structure will meet the existing track tolerances.

E. Mounting of the key-by contactor case and interconnection wiring shall be in accordance with the approved installation drawings.

F. All equipment described in this Section shall be painted in accordance with the requirements of the Miscellaneous Components and Products Section of these Specifications. The finish color shall be black, except for the head section of the trip arm which shall be painted yellow.

G. After relocation all parts of the automatic train stop that are not painted or made of non-corroding material shall be coated with an approved corrosion-preventive grease. All unused threaded outlets shall be suitably plugged or capped.

3.02 TESTING

A. Tests of the automatic train stop layouts and key-by contactors shall be as specified in the Signal System Tests Section of these Specifications.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16829

BONDED INSULATED JOINTS

PART 1 - GENERAL

1.01 DESCRIPTION

A. The work to be done under this Section consists of the manufacture, inspection, factory testing, delivery and installation of bonded insulated joint plug rails in welded rail. The work includes thermite field welds.

B. The work to install and field weld all insulated joint plug rails required in this Contract shall be performed by an qualified and approved track installation contractor.

C. Insulated joints shall be installed at all locations as shown on the Contract Drawings.

1.02 SUBMITTALS

The Contractor shall submit the following to the Engineer for approval:

A. Calibration certificates for all testing equipment used to perform the tests specified herein;

B. The proposed method of packaging, handling and loading all track appurtenances and other track material for approval;

C. Working drawings showing the proposed method and equipment for handling and installing bonded insulated joint plug rails, and conventional plug rails showing locations of field cuts in existing track, and locations of field welds in CWR, and length of rails, for review and acceptance prior to the commencement of work;

D. Prior to the initiation of thermite welding, submit detailed specifications showing the proposed quick preheat thermite kit, method and procedure for thermite welding. The specifications shall comply with these Specifications and that of the weld kit manufacturer, and shall include the name of the weld kit manufacturer and details of the following operations:

1. Rail preparation;

2. Rail end spacing, tolerances, and procedure to maintain rail gap during the welding operation including tye type of hydraulic rail puller and profile rail grinder;

3. Rail alignment, including the type of alignment beam system;

4. Placing and securing of prepared molds;

5. Preheating of rail, including method, temperature, and time;

6. Crucible tapping procedures, including duration of weld an cooling time;

7. Trimming and grinding of weld.

E. The Contractor shall submit a complete and current record of all field welds showing the following for each weld:

1. Location by station, track designation and rail;

2. Date and time;

3. Rail weight and section, mill brand, year rolled, heat number;

4. Name of manufacturer of field weld kit used;

5. Air temperature, rail temperature and approximate weather conditions;

6. Rail gap to nearest 1/16 inch;

7. Track alignment and construction (curve, tangent, grade, etc.);

8. Name of Engineer or authorized representative present;

9. Name of Contractor's foreman present.

F. The Contractor shall submit for approval procedures for adjustment of CWR and rail anchoring prior to commencing work. This Contractor shall also provide a site specific record of work on a daily basis which shall include the following:

1. Location by engineering station, track designation, and rail;

2. Date and time;

3. Air temperature, rail temperature and weather conditions;

4. Rail gap at time of anchoring to nearest 1/16 inch;

5. Adjustment applied (type and movement).

G. The Contractor shall also submit the following for review and approval by the Engineer:

1. Sample thermite field welds and their certified qualification test and inspection results;

2. Supervisor and field welder's qualification certifications for each welder who will perform work on this Contract. Weld supervision and all welders shall be required, upon request of the Engineer, to submit their qualifications during the duration of the project;

3. Certification that persons who shall perform ultrasonic testing of field welds have previously tested a minimum of 250 welds;

4. Certified ultrasonic inspection results for all field welds;

5. Design of bonded insulated joint plug rails.

1.03 QUALITY CONTROL

A. General

1. Perform all field weld hand testing and inspection at no additional cost to the Contract.

2. All field weld hand testing and inspection shall be performed by an approved certified independent testing laboratory. The Engineer may audit the operations to ensure that the inspection and test are being performed in accordance with approved procedures and in compliance with these Specifications.

3. To be accepted, all rail, welds, and track must fulfill all the requirements of these Specifications.

B. Field Weld Qualification Inspection and Testing

1. Prior to field welding, the welds, and each welding crew shall be qualified as specified below. Welding crews shall prepare, in accordance with the methods and procedures for thermite field welding submitted and approved under Article 1.02-A of this Section, at least three samples of each type of thermite weld; heat treated rail welded to heat treated rail, heat treated rail welded to control cooled rail, and control cooled rail welded to control cooled rail. Each welding crew shall perform at least one of each type of the sample welds. The sample welds shall join two pieces of rail a minimum of 30 inches in length each.

2. Test three sample welds from each type of rail as follows:

   a. Perform the Rolling Load Test as specified in Article 1.03.B.4 of this Section on one sample weld from each type of rail.

   b. Perform the Slow Bend Test specified in Article 1.03.B.5 of this Section on a second sample weld from each type of rail.

   c. Perform the Hardness Test specified in Article 1.03.B.6 of this Section on a third sample weld from each type of rail.

3. Rolling Load Test

   a. Test one sample weld from each type of rail on a 12 inch stroke rolling load machine.

   b. Welds tested under this Article shall sustain without failure not less than 2 million cycles of repeated loadings of a 44,000 pound wheel load.

4. Slow Bend Test

   a. Subject a second sample weld from each type of rail to the Slow Bend Test described in the Proceedings of the AREA, Volume 68.

   b. The Acceptance criteria for this test shall be a minimum deflection of 1 inches and 100,000 pounds per square inch modulus of rupture.

5. Hardness Test

   a. Longitudinally cross-section a third sample weld of each type of rail for a distance of one foot each side of the weld, micro-etch and test by the Brinell Hardness Testing using a 150 kgf diamond sphero-conical penetrator.

   b. Test the rail for hardness on the sectioned face at points on a grid pattern of 1/8 inch increments for one inch on each side of the centerline of the weld, and on a grid pattern of 1/2 inch increments beyond until the hardness readings coincide with the hardness of the parent rail metal.

   c. Inspect the micro-etched section for compliance with field weld requirements of full penetration, complete fusion and internal defects specified herein.

   d. The weld materials and the rail one foot away from the weld shall have Brinell hardness numbers between 248 and 280.

6. Approval of the weld kit, welding process, and welding crews will depend upon all sample welds satisfying the specified requirements. Should any sample weld fail to satisfy the specified requirements, the welding process, the welding crew, or both, will not be qualified for the work.

7. Employ a supervisor and welders for each welding crew, trained and certified for the performance of thermite field welds by the manufacturer supplying the weld kits. Should any supervisor of the welding crew be replaced during the work the welding crew shall be re-qualified under the new supervisor. Welding supervision or the welders maybe required to show proof of certification if requested by the Engineer.

8. Prior to performing welds in specified work, satisfactorily qualify the welds and welding crew as specified herein.

C. Field Weld in-Track Testing

1. During field welding, the Contractor shall hand test and inspect all field welds as specified herein to ensure compliance of all field welds daily to the requirements of these Specifications.

   Each field weld shall have full penetration and complete fusion with no evidence of surface or internal fissures, cracks, porosity or slag type defects.

2. Ultrasonic Testing

   a. Inspect all field welds ultrasonically and daily in accordance with the recommendations of the Nov. 29-30 1983 Proceedings of Association of American Railroads entitled ."Railroad Rail Welding" pages 191-205. Weld quality shall meet the requirements of Article 3.04 of this Section.

   b. Identify each ultrasonic test including the engineering station and track and rail identity. Submit a letter of identification with each test to the Engineer, giving comments on any irregularities found in the weld, whether the weld passes or fails the above recommendations and the requirements of Article 3.04 of this Section.

3. Physical Inspection

Visually and dimensionally inspect each field weld daily to determine conformance with the alignment and finishing tolerances specified herein.

4. Defective Welds

Any defective welds detected by the above testing and inspection shall be removed by saw cutting in a new rail not less than 19' - 6" in length and installing two thermite welds. All corrective procedures, as above, for the removal of defective welds shall be at the Contractor expense.

D. Tolerances

1. After insertion of bonded insulated joint plug rails, the final established gauge, crosslevel, super-elevation and vertical and horizontal alignment for the affected track shall be within the following tolerances:

a. The deviation from zero cross level at any point on tangent or from designated elevation on curves between spirals may not be more than 1/8 inch.

b. The variation in cross level on spirals in any 31 feet shall not be more than 1/8 inch.

c. The difference in cross level between any two points less than 62 feet apart on tangents and curves between spirals may not be more than 1/8 inch.

d. The deviation from designated elevation on spirals may not be more than 1/8 inch.

e. The deviation from uniform profile on either rail at the mid-ordinate of a 62 foot chord may not be more than 1/4 inch.

f. The variation of track gauge shall not exceed plus or minus 1/16 inch unless otherwise directed by the Engineer.

E. Qualification Tests - Bonded Insulated Joints - Plug Rails

1. Electrical Resistance Test - A rail joint shall be assembled in accordance with manufacturer's recommendations and supported on non-conducting material. With 500 volts dc applied to the rail across the bonded insulated joint for a duration of three minutes, the current flow through the joint should be measured to the nearest 0.01 micro ampere. The minimum acceptance resistance for the test shall be 10 megohms. With 50 volts AC applied to the rail across the bonded insulated joint for a duration of three minutes, the impedance shall be measured with an accuracy of plus or minus 2%. This test shall be repeated three time, once with a frequency in the range from 20Hz to 100Hz, again with a frequency in the range from 200Hz to 1000Hz and again in the range from 2000Hz to 10KHz. The minimum acceptable impedance for any of these tests shall be 10,000 ohms.

2. Rolling Load Test - The rail joint used in the Electrical Resistance Test shall be mounted on a 33 inch stroke rolling load test machine supported on 36 in. centers with the joint centered between the supports. Apply a 44,400 pound wheel load on the rail for 2,000,000 cycles and measure and record to the nearest 0.001 in. the deflection of the rail at the centerline of the joint. The deflection at the ends of the joint shall also be measured at every 500,000 cycles. The wheel path shall travel from a point 6 in. from the center of the joint to a point 9 in. outside the opposite end of the joint. Total range of deflection of the joint shall not exceed 0.065 inches during the test and the joint shall show no

evidence of failure by bending. The electrical resistance test shall then be repeated and the test results shall be within the acceptance criteria specified.

3. Longitudinal Compression Test - The assembled joint shall be sawn in half where the rails are joined together in a manner which will prevent overheating and damage to the epoxy bond. The cut shall be perpendicular to the centerline of the top of rail.

   A fixture or device shall be used so that the reaction at the sawn ends occurs only on the face of the joint bars when a load is applied to the centroid of the rail at the opposite end. The load shall be applied in increments of 25,000 pounds, maintaining each load increment until the deflection of the rail stops before increasing the load. The load shall be increased to 650,000 pounds and a record of loading and differential movement of the rail measure to 0.00 in. shall be measured for each increment. The joint shall show no indication of slippage prior to reaching a compressive load of 650,000 pounds and the movement shall be less than 1/8 in. in any direction. The relative position of the rail and joint bar shall be within 1/32 in. of its original value when the load is removed.

4. The Contractor may submit certification and test results that an insulated joint has passed the qualification testing specified herein.

1.04 RAIL

A. Shipping. Load rail and bonded insulated joint plug rails only into rail cars or specially equipped vehicles which are in good order.

B. Handling Handle rail, bonded insulated joint plug rails and other track material in a manner that will not damage the material in any way.

PART 2 - PRODUCTS

2.01. MATERIAL

A. New control cooled carbon steel rail in 78 foot or longer lengths, shall be furnished in sufficient quantity for the completion of work as indicated.

B. The materials shall be loaded, transported, unloaded and distributed by the Contractor.

C. Furnish quick preheat thermite weld kits.

D. Furnish bonded insulated joint-plug rails, as follows:

1. Provide bonded insulated joints shop fabricated into plug rails for installation into CWR. Plug rails shall be 39'-0" in length.

2. All rail furnished for plug rails shall be fully heat treated.

2.02. Joint Bars

1. The joint bars shall be 36 inch, full face contact design.

2. Material. Fabricate joint bars from quenched carbon steel conforming to AREA Manual for Railway Engineering, Chapter 4, Specification for Quenched Carbon-Steel Joint Bars.

3. Configuration. Provide full-face contact joint bars conforming to the configuration of the rail, as required. Joint bars shall be smooth and straight. The inside face of the joint bars shall have insulating material pre-bonded, and be smooth with no branding or stamping.

4. Fabrication Tolerances

   a. Fishing Height. Within plus or minus 1/64 inch of the dimension shown on the approved shop drawings.

   b. Straightness. All portions of the joint bars adjacent to the rail shall be straight within a tolerance of plus or minus 1/32 inch, measured with a 36-inch straight edge.

   c. Length. Within plus or minus 1/8 inch of the dimension shown on the approved shop drawings.

5. Insulating Material.

   All insulating materials shall be of high pressure, laminated design, impervious to oil, grease and water, and shall have electrical resistance characteristics equal to or greater than fiber insulation meeting the requirements of the AAR Manual, Part 116, Signal Section Specification 216-46. End posts shall project 1/4 inch, plus or minus 1/16 inch below base of rail and shall be 3/16 inch thick.

   Bonded insulated joint to be cemented together with adhesive and bolted together with six high strength, 1 inch diameter bolts. Provide bolts, nuts and flat washers conforming to the chemical and mechanical requirements of ASTM Designation A490, Quenched and Tempered Alloy Steel Bolts for Structural Steel Joints, and having Class 2A and 2B thread fit. Provide a positive means for maintaining the tension in the bolts through in-service vibrations by a prevailing lock nut complying with Industrial Fastener Institute Standard IFI-100 and IFI-101, or approved equivalent. Locate and size the bolt holes in conformance to the drilling as specified in AREA Specifications. Flat washers, if required, shall be hardened A-325 or A-490 and tempered carbon steel.

C. Provide new Pandrol Modified "e" clips for all insulated joints.

PART 3 - EXECUTION

3.01 INSTALLATION OF BONDED INSULATED JOINT PLUG RAILS

A. The Contractor shall install bonded insulated joint plug rails at the required locations within CWR territory.

B. Bonded insulated joints shall be installed as suspended joints and existing crossties shall be re-spaced as necessary to achieve this requirement.

C. Joints created by installation of the insulated joint plug rails shall be field welded by an approved thermite process.

D. Bonded insulated joints at resilient fasteners shall be secured with the modified "e" clips.

E. Rail removed for the installation of the insulated joint plug rails shall be salvaged as specified in this Section.

3.02 REMOVAL OF BONDED EXISTING INSULATED JOINT PLUG RAILS

A. The Contractor shall remove existing insulated joint plug rails and install standard rail at required locations within CWR.

B. Removal of an existing insulated joint plug rail shall be accomplished by cutting the plug rail with a rail saw or and abrasive cutting disk only, 1'- 6" inside both existing thermite welds, which shall result in the proper salvage of a 36 foot (36') long bonded insulated joint plug rail.

C. The installation of standard running rail shall be accomplished by cutting out the existing thermite welds with a rail saw or an abrasive cutting disk only, 1'- 6" outside both existing thermite welds and installing a 42 foot minimum length of rail which shall be field welded in track by an approved thermite process.

D. Bonded insulated joint plug rails removed from track shall be salvaged as specified.

3.03 ADJUSTMENT OF CONTINUOUS WELDED RAIL

A. Rail Temperature

1. Determine rail temperature by an AREA standard rail thermometer as specified in the current AREA Manual for Railway Engineering, Chapter 5, Plan Number 34-71.

2. Determine the temperature of the rail by placing the rail thermometer on the shaded side of the rail base next to the web and leaving it there for not less than five minutes and until no change in its reading is detected.

3. Record rail temperature readings of CWR at the time of rail laying.

B. Adjustment of CWR

1. The Contractor shall obtain records from the Engineer of the installation temperature of CWR at locations where CWR is to be cut.

2. When the rail is cut and the rail temperature is less than the rail temperature when originally installed or if the records are not available the CWR must be adjusted for thermal expansion.

3. Adjustment of CWR shall include removal of rail anchors for 1/4 mile in both directions of cut and expanding rail by either natural or applied heat to obtain zero thermal stress. Any methods for obtaining zero thermal stress shall be approved by the Engineer.

4. Before allowing rail to expand, an appropriate length of rail shall be removed to allow for expansion. This rail end gap (G) shall be determined by the formula:

$G = (t-T) LK$
where:

G = Rail end gap in inches
t = Zero Thermal Stress temperature (95°Fahrenheit)
T = Rail temperature in degrees Fahrenheit
L = Length in feet of rail to be expanded
K = Coefficient of thermal expansion for steel rail = 0.000078

5. Any alternate method for allowing rail to expand shall be submitted to the Engineer for review and approval.

6. After rail is thermally expanded, weld rail ends, re-apply anchors immediately, recording new adjusted temperature on form to be forwarded to the Authority and the operating railroad. Such form shall identify:

   a. Location of cut by mile post to the nearest tenth

   b. Location of cut by rail as N.S.E. or W.

   c. Temperature of rail before cutting

   d. Temperature of adjusted rail

   e. Air temperature

   f. Length of rail expanded in either direction

7. Once thermally expanded, joints in CWR shall be field welded immediately.

C. Rail Anchoring Temperature

1. The Contractor shall anchor rail when the temperature is within the zero thermal stress temperature range. When zero thermal stress temperature is obtained, begin anchoring immediately. Rail temperature shall remain within the specified zero thermal stress range until the rail is fully anchored. If the rail temperature deviates from the specified zero thermal stress range, cease anchoring until the rail temperature returns to within the specified range.

2. When rail temperature is below the zero thermal stress temperature range, an approved rail heating device may be used for expanding the CWR to make proper adjustment.

3. During anchoring, it is important to ensure uniform expansion. To control this mark the quarterpoint of strings on a rail and tie plate so the amount of expansion can be accurately determined then make sure the rail expands as follows.

   1/4 Point - 1/4 of Required Expansion
   1/2 Point - 1/2 of Required Expansion
   3/4 Point - 3/4 of Required Expansion

   a. In the event the first half of the heated CWR string does not have the required expansion at each quarter point, when heating artificially back the heater over the heated portion, without applying heat and then reheat the rail until the necessary expansion is obtained.

   b. The rail shall be fully clipped immediately behind the heater and must be clipped while the rail is within the zero thermal stress temperature range.

4. The temperature of a rail, when being clipped opposite an anchored rail, shall be within plus or minus five degrees Fahrenheit of the temperature of the anchored rail when the anchored rail was anchored.

5. Record the rail temperature and related information during the rail anchoring process. Record the rail temperature every 30 minutes during the anchoring process at the anchoring location.

D. ZERO THERMAL STRESS

1. The Contractor shall install, anchor, join, and field weld CWR to produce zero thermal stress in the rail at 90 degrees Fahrenheit, to 110 degrees Fahrenheit.

2. Zero thermal stress may be achieved by heating. Rail pulling shall not be allowed. All methods for artificially obtaining zero thermal stress must be acceptable to the Engineer. Take care to prevent any damage to trackwork components during any heating process. If any damage occurs, make repairs at no additional costs to the Authority.

3. Vibrate rail during thermal adjustment to relieve internal rail stresses. Continue vibration during the full period of rail length correction. Mechanical vibrators used for relieving internal rail stress shall be of a type acceptable to the Engineer and shall not damage the CWR. Continuous welded rail shall be vibrated whether installed at ambient temperature or distressed artificially.

3.04 THERMITE FIELD WELDING

A. General

1. The Contractor shall join strings of CWR laid in tracks together by the thermite welding process except where insulated joints, are located.

2. Field welds shall not be located within the following area unless approved, or directed, by the Engineer:

   a. Within ten feet of a field weld in the opposite rail;

   b. Within 18 feet of a field weld in the same rail;

   c. Within 18 feet from the center of any bolted joint;

   d. Within 3 feet of a shop weld;

   e. Within 10 feet of a bridge deck;

   f. Within 20 feet of a highway crossing;

   g. On a tie plate.

B. Weld Quality

Each field weld shall have full penetration and complete fusion with no evidence of surface or internal fissures, cracks, porosity or slag type defects.

C. Welding Requirements

1. The Contractor shall use approved weld kits that are self-tapping, and require minimum preheating.

2. Rail ends shall be saw cut at right angles to the rail. The Contractor shall clean the surface of the rail for a length of approximately six inches from each end, free of all grease, dirt, loose oxide, scale and moisture. All burrs and lipped metal which would interfere with the proper fit of the molds shall be removed. Torch cutting of rails is prohibited.

3. Prior to field welding strings of CWR, the Contractor shall adjust the length of the CWR strings for zero thermal stress temperature, vibrate the rail to relieve internal rail stresses, and fully anchor the rail.

   At the time of field welding, the rails shall be aligned to produce a weld which, with respect to alignment, shall be in accordance with current AREA Specifications for Fabrication of Continuous Welded Rail modified to require a slight crown in the running surface to assure a flat surface after the weld has cooled. The maximum vertical offset permissible is 0.015 inch using a 36 inch straightedge. The maximum horizontal offset in the rail head using a 36 inch straightedge is 0.060 inch. The maximum combined vertical offset and crown camber determined using a 36 inch straightedge shall not exceed 0.060 inch. Negative camber or dip shall not be permitted.

4. The proper rail end alignment shall be achieved by the use of an approved alignment device designed and manufactured for this purpose. In no case will the use of track jacks or track spikes be allowed for rail end alignment.

5. At the time of field welding the rail gap shall be as specified by the manufacturer of the weld kit. If the rail gap is not within the recommended tolerances for field welding, the Contractor shall un-anchor the CWR strings for 300 feet each side of the rail gap and readjust each CWR string for 300 feet within the specified zero thermal stress range. The Contractor shall re-anchor the CWR before performing a field weld. Should the rail gap on anchored CWR be larger than the manufacturer's recommended gap after the CWR strings have been readjusted for zero thermal stress, the Contractor shall saw a length of rail from one end of one of the anchored CWR's and insert a rail not less than 19 feet long to provide the manufacturer's recommended gap for field welding. At locations where the rail gap is smaller than the manufacturer's recommended gap, the recommended gap shall be obtained by sawing a piece from the rail.

   a. Thermite field welding is prohibited when the rail temperature is below 32 F., measured on the shady side of the rail.

   b. When the rail temperature is between 32 F. and 50 F., a hydraulic rail puller, designed and manufactured for this purpose, must be used to maintain proper rail end gap. The puller shall be left in place until the rail has cooled to below 700 F. Any movement of the rail before the weld has cooled to at least 700 F. will result in the weld failing. It is important that the weld is not subjected to a sudden strain by releasing the hydraulic pressure too quickly.

   c. The hydraulic rail puller shall not be used to establish the proper rail end gap.

6. The Contractor shall trim and grind weld to meet the following requirements and as otherwise specified by the manufacturer:

a. Finish the top and sides of the weld at the rail head to within plus 0.005 inch or minus 0.00 inch of the parent section.

b. If the field weld is located within three inches of the edge of a rail support finish the weld at the rail base to within plus 0.01 inch or minus 0.00 inch of the parent section.

c. Finish the web zone and the remainder of the rail weld to within plus o.375 inch or minus 0.00 inch of the parent section. Finish grind the weld to eliminate visible cracks.

d. Eliminate notches created by offset conditions by grinding to blend the variations. Remove all protrusions or gouges in the welded area and blend the weld area into the rail contour by grinding in a manner which will eliminate fatigue crack origins. The Contractor shall remove, by grinding, all defects visible to the unaided eye, except if removal by grinding cannot be accomplished without damaging the rail, the Contractor shall remove the weld. The Contractor shall take precautions to avoid excessive pressure during grinding of the weld in order to prevent overheating of the rail surface.

e. The Contractor shall complete all heavy grinding after the weld has reached the ambient rail temperature, or as recommended by the manufacturer. Removal of the weld upset by the use of a saw or other such device is prohibited.

f. Finish rail grinding shall be completed prior to the operation of trains over the weld. Finish grinding of the weld shall be accomplished with an approved rail profile grinder. The use of hand held grinders is prohibited.

7. Thermite field welds shall be made in accordance with, and shall not deviate from, the manufacturer's recommendations and AREA Chapter 4. Short cuts in the recommended pre-heating process are prohibited.

8. Welding during inclement weather such as rain, mist, snow, etc. is prohibited.

3.05 TRACK ALIGNMENT AND GAUGE

The installation of plug rails shall not disturb existing vertical, horizontal track alignment, or track gauge. Should the Contractor alter or disturb track alignment or gauge while conducting the work the track shall be repaired to the tolerances specified at no additional cost to the Authority.

3.06 SALVAGE

The Contractor shall recover all bonded insulated joint plug rails and conventional lengths of rail removed from track. This material shall be properly loaded, transported, unloaded and neatly stockpiled at a location to be determined by the Engineer.

3.07 TRACK USAGE

No work under this section shall be performed without proper authorization from the Authority.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16830

RUNNING RAIL BONDING

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the furnishing and installing of all necessary material to bond the track running rails for traction negative return and signal track circuits.

1.02 QUALITY ASSURANCE

A. The Contractor shall install each welded bond and mechanical connector in accordance with the requirements of this Section.

B. The Contractor shall test each welded bond in accordance with the requirements of the Signal System Tests Section of these Specifications.

1.03 SUBMITTALS

A. Catalog cuts, descriptive literature and procedures for the following shall be submitted:

B. Material composition, electrical and mechanical characteristics for power bonds, signal bonds, and track circuit split bolt connectors.

C. Field installation procedures for welded signal and power bonds.

D. Field test procedures for welded signal and power bonds.

E. All mechanical devices for securing and protecting running rail bonding.

F. Plan showing detailed final design for bonding of special trackwork to assure that all components of the trackwork are properly connected electrically.

PART 2 - PRODUCTS

2.01. MATERIALS

A. The bonds and materials specified herein shall be manufactured for welding to the running rails by the exothermic process. Bonds, bonding materials and types of molds shall be approved by the Engineer. The type of bonding required shall be as follows:

B. Power Bonds

1. All non-insulated joints in single or double rail track circuit territory including guard-rail joints, shall use 250 Kcmil size, 14 inches long bonds, two for each joint, as manufactured by Erico Products, Inc., Dwight and Wilson Co., United States Steel, or approved equal.

2. Power bonds for frog, switch fouling connections and expansion joints shall be extra flexible 2-500 Kcmil as specified in Authority's Standard Specifications P-141.

C. Signal Bonds

1. Bonding for non-insulated rail joints in signal rails shall employ railhead bonds, 7/32" x 6-1/2", two for each joint, as manufactured by Erico Products, Inc., Dwight and Wilson Co., Thermoweld, Inc. or approved equal.

2. Track circuit rail connections shall employ two (2) railhead bonds, 7/32" x 6-1/2", that shall be welded to the base of the rail and connected to the track lead with a split bolt connector as shown on the Contract Drawings. The two railhead bonds shall be connected to each other with two split bolt connectors and a No.8 AWG connector cable.

D. Impedance bond track leads shall be extra flexible 500 Kcmil in accordance with the Authority's Standard Specifications P-141.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Power bonds shall be installed at all non-insulated rail joints.

B. The two railhead bonds for each track circuit connection shall be installed side-by-side as shown on the Contract Drawings.

C. Frog, switch jumper, and crossbonding shall be installed at locations shown on the Contract Drawings, and as specified herein. All pieces of the special trackwork shall be bonded in accordance with the approved plans in order to establish electrical continuity and conductive capacity for traction power return and signal track circuits.

D. For all rail joint bonds, impedance bond connections to the running rails, switch and frog bonds, and expansion joint bonds, the surfaces of the rails where the bond is to be applied shall be ground clean with a reinforced grinding wheel, of a type as recommended by the bonding material manufacturer. The use of vitrified grinding wheels will not be allowed. After grinding, the surface shall be cleaned with an approved non-toxic solvent to remove all traces of grease and dirt.

E. After the surface has been ground and cleaned, the surface shall be heated to drive out any moisture. The cable bond shall then be welded by the exothermic process in such a manner as to ensure a thorough mechanical and electrical connection.

F. The welding material shall consist of a copper exothermic mixture employing tin in an amount to effectively constitute 4.5 percent to 5.5 percent of the resulting weld metal. The resulting weld metal shall be of high electrical conductivity and shall have a minimum tensile strength of 39,000 pounds per square inch. The tensile strength shall be determined by tensile tests performed on one-half (1/2) inch nominal diameter tensile specimens (without flaws) cast in graphite molds.

G. The casting of the test specimens shall be by the direct reduction of the exothermic mixture and the flowing of the weld metal into a graphite mold to form the one-half (1/2) inch diameter specimens.

H. Before beginning work on these bonds, the Contractor, at his expense, shall require each welder to weld in the field under conditions similar to those of the regular installation, not less than three complete rail connections, and as many more as the Engineer considers necessary to determine that the welds are being made satisfactorily. Such welds shall be subject to inspection and test by the Engineer, and his approval as to method and quality of workmanship will depend on the results of these inspections and tests.

I. It is required that each rail connection be thoroughly welded to the rail and, to reduce the possibility of any of these welds breaking in service, the Engineer reserves the right to require a test of each weld by hammer and striker, or in any other manner which in the opinion of the Engineer is reasonable.

3.02 TESTS

A. The Contractor shall demonstrate that the bonding is in accordance with the requirements of this Section, as shown on the Contract Drawings, and as specified in AREMA Signal Manual Part 8.1.30.

B. Any bond, weld, or connection installed by the Contractor and found to be defective prior to acceptance, shall be removed and a new bond shall be installed as part of the work.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16840

JUNCTION BOXES

PART 1 - GENERAL

1.01 DESCRIPTION

This Section specifies furnishing and installing of junction boxes with all associated hardware for signal cable terminations.

1.02 QUALITY ASSURANCE

The Contractor shall inspect each junction box after it has been installed and wired. This inspection shall be conducted in conformance with the requirements of the Contractor's Installation Inspection Procedure as approved by the Engineer.

1.03 SUBMITTALS

The Contractor shall submit the following to the Engineer for approval:

A. Drawings of each type junction box he proposes to furnish including terminal boards, terminals, wiring, mounting details, and any other integral parts. Where the junction box forms part of the layout, as specified elsewhere within these Specifications, the junction box submittal may be made as a part of the Contractor's total layout submittal.

B. An Installation Inspection Procedure for each junction box.

C. Drawings showing the method of installation for each type junction box proposed to be furnished.

1.04 DELIVERY, STORAGE, AND HANDLING

Junction boxes shall be protected from damage throughout delivery, storage, and handling.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Junction boxes for multiconductor signal cables

1. Junction boxes for multiconductor signal cables shall be of weatherproof, gasketed design and single-door, molded fiberglass construction. The thickness of the housing sides and door shall be one-quarter inch (minimum), with the bottom and back being three-eighths inch thick. The housing shall comply with the applicable standards of ASTM-E-84 for exterior walls. Interior paneling shall comply with a flame spread of 0-20 and a fire rating of 7 in accordance with ASTM-E-84. The fiberglass shall have ultra-violet ray protection by special additives. The outside color shall be gray or off-white, as approved. Provide the junction boxes complete with terminal boards and AAR double post, quick test type, terminals as specified within the Miscellaneous Components and Products Section of these Specifications.

2. Each junction box shall contain twenty percent spare terminals, unless otherwise directed by the Engineer.

B. Junction boxes for signal power cable

1. Junction boxes for signal power cable shall be NEMA 4X weatherproof gasketed design, single door molded fiberglass construction. The thickness of the housing and door shall be one-quarter inch minimum. Terminal board shall be made of fiberglass three-eighths of an inch thick. Cable terminals and lugs shall be in accordance with the MBTA Standard Specifications Section 16050, Article 2.14, H.

2. The junction box door shall be fastened to its housing with a 16 gauge stainless steel hinge continuous over the full height of the door. Each door shall be have a latching mechanism of a three-point-lock design. The handle shall be designed for the use of a standard Authority's padlock.

3. Warning signs "DANGER HIGH VOLTAGE - KEEP OUT" shall be affixed to each signal power cable junction box. The word DANGER shall appear in a red oval on a black panel. The remainder of the warning shall be in black lettering. Signs shall be constructed of steel.

C. All junction boxes shall have provisions for either wall or ground mounting. Wall mounted junction boxes shall be sized to fit within existing safety niches, unless directed otherwise by the Engineer.

2.02 FINISH

A. The interior finish and color of multiconductor signal cable junction boxes specified herein shall be the Manufacturer's standard.

B. The exterior of the multiconductor signal cable junction boxes shall be finished in accordance with the requirements of the approved manufacturer's standard. The final color shall be grey or -white as approved.

2.03 SECURITY

A. All junction boxes shall be provided with a means for applying locks as described in the Miscellaneous Components and Products Section of these Specifications.

B. Junction boxes shall be equipped with a locking device and capable of being secured, upon closure, with the Authority's standard padlock.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Signal junction boxes shall be installed to terminate signal cables, as shown on the approved drawings.

B. Grounding of junction boxes shall be as specified within the Grounding of Equipment Section of these Specifications.

C. After having installed the junction boxes in their final locations, the Contractor shall stencil a permanent identification, employing nomenclature to be provided by the Engineer. The nomenclature will consist of not less than four symbols nor more than eight. After having stenciled the nomenclature on the cover of the box, the identification shall be further protected by a coat of clear exterior grade transparent protective approved covering.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16850

ELECTRIC HEATING EQUIPMENT

PART 1 – GENERAL

1.01 DESCRIPTION

A. This Section specifies the installation of electric unit heaters in accordance with MBTA Standard Specification Section 16850 and as modified herein and Section 15600.

B. Related Section 15600 - Heating, Ventilating and Air Conditioning

1.02 QUALITY CONTROL

A. The work shall comply with the applicable provisions of Section 16050.

B. The work under this Section shall conform to applicable requirements of the Massachusetts Electric Code and Energy Code.

PART 2 – PRODUCTS – Not Used

PART 3 - INSTALALTION

3.06 UNIT HEATERS

Mechanical Contractor shall furnish and install electric unit heaters. Electrical Contractor shall install all wiring required to power the unit heater in accordance with Division 16 of this specification.

PART 4 – MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. Separate measurement and payment will not be made for Electric Heating Equipment work of this section, supplied to the mechanical contractor, but all costs therefore shall be included in the Contract Lump Sum Price for the work as indicated herein.

4.02 PAYMENT

A. Power wiring of Electric Heating Equipment as specified in this Section will be paid for at the Contract Lump Sum Price for Electric Heating Equipment work.

4.03 PAYMENT ITEM

Item No.	Item Description	Unit
1681.000	ELECTRIC HEATING EQUIPMENT	LS

END OF SECTION

SECTION 16855

INTERNAL WIRE AND CABLE

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies furnishing and installing wire and cable in the central instrument houses (CIHs), wayside cases, and in enclosures where it will not be exposed to the elements. All intra-rack and rack-to-rack wire and cable shall conform to the requirements of this Section.

B. Stranded wire, including individual conductors of multi-conductor cables covered by this Section, shall be TEFZEL® per Military Specification, MIL-W-22759 and the Specifications contained herein.

1.02 QUALITY ASSURANCE

A. Quality Assurance provisions of the applicable Military Specifications shall be followed in the manufacture of wire covered by this Section. The Contractor shall be responsible for witnessing and reporting the results of any and all required qualification tests. One-half of each qualification sample shall be retained for the Contractor's evaluation and the remaining one-half shall be forwarded to the Engineer for final approval. The Contractor shall be responsible for monitoring the manufacturer's conformance to the quality assurance requirements and the Engineer reserves the right to audit conformance in accordance with the MBTA Standard Specifications.

B. All other work covered by this Section shall be accomplished in compliance with a Quality Assurance Program that meets the intent of the ASQC Standard Cl-1985 General Requirements for a Quality Program.

C. Multi-conductor cables shall be tested to verify conformance with the requirements of this Section as follows:

1. Individual conductors shall be tested per the requirements specified herein for Stranded Wire for General Use, prior to cable assembly.

2. All finished cables shall be placed in water at room temperature. After 48 hours immersion and while still immersed, all conductors shall be tested for breakdown at a voltage of 2,500 volts (rms) for five minutes.

3. Samples of finished cable fabricated from each batch of cable outer sheath material shall be flame-tested per IEEE Standard 383-1974.

1.03 SUBMITTALS

In accordance with the requirements of Section 01300 – Submittals, the Contractor shall submit the following for the Engineer's approval:

A. Complete technical data verifying that the internal wire and cable which the Contractor proposes to furnish in compliance with the requirements of this Section;

B. Qualification samples;

C. Reports of all qualification tests witnessed by the Contractor;

D. Certified test reports of all breakdown tests conducted on finished cable;

E. Certified tests reports of all flame tests conducted on finished cable;

F. Submit a Certificate of Compliance to the requirements of the Specification. The certificate shall list all requirements and shall show a confirmation for each item. The certificate is to be signed by the Contractor's quality control officer.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Stranded Wire for General Use

1. General Requirements

a. The requirements for TEFZEL® wire described herein shall consist of this Specification and the issue in effect of Military Specification MIL-W-22759. Where there is a discrepancy between this Specification and the requirements of the applicable Military Specification, the requirements of this Specification shall govern. The requirements of this Specification shall also be used where the Military Specification refers to "...the requirements of the applicable military specification sheet."

b. All internal stranded wire furnished and installed under this Contract shall be subject to the following requirements:

(1) Conductor: Concentric-Lay-Stranded, Annealed Copper per ASTM B-8

(2) Coating: Tin or Lead per ASTM B-33 or B-189

(3) Insulation: ETFE – Ethylene-Tetrafluoroethylene or E-CTFE - Ethylene-Chlorotrifluorethylene per MIL-W-22759

(4) Construction: per Table A.

(5) Performance: per Tables B. and C.

TABLE A. Construction Details

Wire Size (AWG)	Conductor Stranding (Strands x Size)	Maximum Diameter Stranded Conductor (Inches)	Conductor Resistance Maximum @ 20 C (Ohms/1000 Ft.)
22	19 x 34	.033	16.2
20	19 x 32	.041	9.88
18	19 x 30	.051	6.23
16	19 x 29	.058	4.81
14	19 x 27	.073	3.06
12	37 x 28	.090	2.02
10	37 x 26	.114	1.26
8	133 x 29	.173	.701

TABLE B. Performance Details

Wire Size (AWG)	Minimum Resistance (Inches of Tape)	Weight Support Bracket	Weight (Pounds)	Tension Load (Pounds)
22	26	A	1.0	1.0
20	26	A	1.0	1.0
18	27	A	1.0	1.0
16	28	A	1.0	2.0
14	19	B	3.0	2.0
12	29	B	3.0	2.0
10	36	B	3.0	3.0
8	35	B	3.0	3.0

TABLE C. Performance Details

Wire Size (AWG)	Mandrel Diameter Life Cycle	Cold Bend (Inches Max.)	Test Load Life Cycle	Cold Bend (Pounds)
22	3/4	1	1.5	3.0
20	3/4	1	2.0	4.0
18	1	1 - 1/4	2.0	4.0
16	1	1 - 1/4	2.0	5.0
14	1 - 1/4	2	2.0	5.0
12	2	2	2.0	5.0
10	3	3	2.0	5.0
8	3	4	3.0	6.0

2. Additional Requirements for Stranded Wire

Type of Insulation	ETFE or E-CTFE	Polyarylene	Polymide Film Tape
Military Specification	MIL-W-22759	MIL-W-81044	MIL-W-81381
Nominal Wall Thickness Size 22-14 AWG	15 mils	10 mils	10 mils *
Nominal Wall Thickness Size 12-8 AWG	20 mils	12.5 mils	]12.4 mils *
Temperature Rating	150 C	150 C	150 C
Blocking Qualifications only)	200 C	200 C	200 C
Color	Contractors Option		
Flammability **	pass	pass	pass
Identification **	30 inch intervals (max.)		
Identification Stripping or Printing Durability	125 cycles (250 strokes) (min.) with 500 grams weight		
Life Cycle	Oven temp. 200 C for 168 hours		
Dielectric Test	2200 volts (rms), 60 Hz		
Accelerated Aging	7 hrs. at 210 C (Quality Conformance Test, Group II; Procedure as in Life Cycle Test)		

2. (continued) Additional Requirements for Stranded Wire

Physical Properties of Insulation			
Physical Properties of Insulation			
Tensile Strength PSI (min.)	5,000	12,000	24,000
Elongation percent (min.)	125	50	40
Chemical Resistance	Test not required		
Shrinkage at 200 +/- 2 degees C (inches max.)	0.125	0.125	0.303
Smoke	200° C	200° C	200° C ***
Thermal Shock			
Cold Bend	-65° C	-65° C	-65° C
Dynamic Cut Through pounds (min.) at 23 degree C with size 20 AWG	90	90	90
Wicking	Test not required		
Abrasion Resistance after Immersion	Same as initial		
* Nominal wall thickness for Polymide film shall be achieved by the following combinations of 50 percent overlapped tape wraps plus an outer 1 mil coating of modified aromatic polymide resin: First wrap. 1/2/.5; Second wrap, .5/1/.5; Third wrap, (Size 12-8 AWG only) .1/1/.1			
** As required by this specification *** Test per MIL-W-22759			

Type of Insulation	ETFE or E-CTFE	Polyarylene	Polylmide Film Tape
Military Specification	MIL-W-22759	MIL-W-81044	MIL-W-81381
Lamination Sealing	NA	NA	230°C 48 hrs
Polyimide Cure Test	NA	NA	required
Resin Coating Durability	NA	NA	****
Humidity Resistance	IR after exposure shall meet initial requirements		
Voltage Rating	600 V RMS	600 V RMS	600 V RMS
Impulse Dielectric Test (100%)	8 KV Peak	8 KV Peak	8 KV Peak
Insulation Resistance	5000 megohms per 1000 ft. (min.)		
Spark Test	Test not required		
Surface Resistance Megohms per inch (min.) Initial and Final	500	500	500
Wet Diaelectric Test Volts (rms)	2500	2500	2500
**** 250 cycles (500 strokes) (minimum) with one pound load.			

3. Special Requirements for Stranded Wire

a. Vertical Flame Test

(1) Single Wire. The test specimen shall be 18 inches in length, and shall be placed vertically within a chamber approximately 2 feet by 1 foot by 1 foot, open at the top and one vertical side (front), which allows a sufficient flow of air for complete combustion, but which is free from drafts. The upper end of the specimen shall be fastened in the chamber by means of a clamp and a weight shall be attached to the lower end of the specimen to hold the specimen taut during the flammability test. The weights shall be the same as those used for the life cycle tests. The specimen shall be marked at approximately 7 inches above the floor of the chamber to indicate where the flame is to be applied.

(2) A flame from a Bunsen burner shall be applied for 15 seconds to the specimen. The Bunsen burner shall be positioned below the test mark on the specimen and at an angle of 20 degrees to the vertical plane of the specimen. The Bunsen burner shall have a 1/4 inch inlet, a nominal bore of 3/8 inch, and a length of approximately 4 inches from the top to primary inlets. The burner shall be adjusted to produce a 3-inch high flame with an inner cone approximately one-third of the flame height. The temperature of the hottest portion of the flame, as measured by a thermocouple pyrometer, shall be not less than 955 degrees C ±30 degrees C. The burner shall be positioned so that the hottest portion of the flame is applied to the approximate position of the test mark on the wire. The time of burning and the flame travel after removal of the flame shall be recorded.

Breaking of the wire specimens in sizes 24 and smaller shall not be considered as a failure.

(3) Bundles. The test specimens shall be prepared by assembling seven single wire specimens, each 14 inches long, into a bundle tied in two places with glass cord or equivalent non-metallic, noncombustible material, 3 inches from each end. The bundles shall be suspended vertically in the test chamber described above. A flame from a Bunsen burner shall be applied vertically to the base of the bundle for 15 seconds. The burner flame shall be adjusted as described for the single wire flame test. The time of burning and flame travel after removal of the flame shall be recorded.

b. Dynamic Cut-Through

(1) The dynamic cut-through test shall be performed at room temperature using a tensile testing machine equipped with a recorder which shall be suitable for recording the force in pounds necessary to force a tungsten carbide cutting tool through the insulation of a finished wire specimen. This cutting tool shall have a cutting edge of .005 inch radius of curvature on a 90 degree wedge. The testing machine shall also be equipped with a 12-volt detection circuit designed to stop the testing machine when the cutting edge cuts through the wire insulation and contacts the conductor.

(2) One inch of insulation shall be removed from one end of an 18-inch finished wire specimen. The specimen shall be placed on a hard, flat surface and the cutting edge oriented perpendicularly to the axis of the wire specimen. The cutting edge shall be forced through the insulation at a constant rate of 0.2 inch per minute until contact with the conductor occurs. The force measured at the time of contact with the conductor shall be recorded. Four tests shall be performed on each specimen with the specimen being moved forward one-inch (minimum), and rotated clockwise 90 degrees between each test. The cut-through resistance shall be the average of the four test result values.

c. Identification

(1) Each stranded wire shall be marked with the following information:

(a) Manufacturer's name

(b) Year in which wire is manufactured

(c) Size of conductor

(d) Type of insulation.

(2) The identifying markings shall be permanent and shall be easily readable and understandable.

(3) Stranded wires used in multi-conductor cable shall be numbered or color-coded in addition to the basic four-part identification.

B. Internal Multi-conductor Cable

1. The outer jacket shall be fabricated of TPR - thermoplastic rubber and shall comply with the requirements of IEEE Standard No. 383 latest revision. The jacket shall be stabilized for outdoor exposure. The outer sheath shall have a nominal thickness in accordance with IPCEA S-68-516, Table 4-16. The barrier tape shall be .005 inch thick, with a minimum 25 percent overlap. The individual conductors shall be sized to meet 150 percent of the load requirements, but shall be no smaller than size 19 AWG, stranded.

2. Cables shall be made by assembling the individual or twisted pairs of insulated wires into a tight, cylindrical form. Individual or twisted pairs shall be assembled helically and with adjacent layers wound in opposite directions.

3. The makeup of multi-conductor cables specified by this Section shall not exceed thirty or fifty conductors for use with vital or non-vital plug connectors respectively. See Specification Section 16857 - Plug Connectors.

4. Multi-conductor cables shall have 10% spare conductors or as shown on Contract Drawings whichever is greater. Reduction in the number of spares is not allowed unless otherwise directed by the Engineer in writing. All spare conductors are to be terminated unless otherwise directed by the Engineer in writing or otherwise specified herein.

5. The cable outer sheath shall be marked with the following information repeated at intervals no greater than 36 inches:

   a. Manufacturer's name

   b. Year of cable manufacture

   c. Number and size of conductors

   d. Type of insulation on wires

   e. Type of outer sheath insulation

   f. Voltage rating.

6. The identifying markings shall be permanent and shall be easily readable and understandable.

PART 3 - EXECUTION

3.01 INSTALLATION

A. General

Internal wire and cable shall be installed in accordance with the applicable requirements of AREMA C&S Manual, Part 10.4.1 and as specified herein.

1. Wires and cables shall be installed in a neat, workmanlike manner. Cables in trays or in troughs shall be laid therein and not pulled in. Cables shall be installed with a minimum amount of

crossover in the trays and troughs and shall not be pulled tightly around bends. All exposed wires and cables entering or leaving equipment racks or housings shall be protected from abrasion by sharp metallic edges.

2. Nylon straps shall be provided and installed for bundling and cabling of conductors where two or more single conductors are exposed in internal rack bundles, cable trays or cable troughs, or whenever wires are to be bundled. Tape shall not be used for this purpose. Straps shall be installed at intervals not greater than five feet along the cable run. Wires of multi-conductor cables exposed by the stripping of the cable jacket for termination's shall be trained in a neat, workmanlike manner and tied approximately every three inches with nylon straps.

3. There shall be no point-to-point redundancy of wires for increased current capacity.

4. Single conductor No. 14 stranded wire shall be used for interconnecting signal junction boxes and lamp compartments and other miscellaneous equipment, unless other size is shown on the Contract Drawings.

5. Ground wires are to be run separately and shall be colored green.

6. Low voltage wiring, less than 50 volts shall be separated, from wiring carrying more than 50 volts, by a minimum of six inches. Where wiring of less than 50 volts crosses wiring of more than 50 volts it shall do so at right angles. Individual ground wires shall be separated from all wiring by a minimum of 6 inches.

B. Module Wiring

Unless otherwise approved by the Engineer in writing, all module wiring shall be accomplished with solderless connections using stranded wire as specified herein. Minimum wire size shall be No. 22 AWG for stranded wire.

C. Rack Wiring

1. Vital Racks

Unless otherwise directed by the Engineer in writing, all vital rack wiring shall be accomplished with approved solderless connections. Wire for vital rack wiring shall be stranded wire as specified herein, minimum size No. 16 AWG, or multi-conductor cables as specified herein.

2. Non-Vital Racks

Unless otherwise directed by the Engineer in writing, all non-vital rack wiring shall be accomplished with approved solderless connections. Wire for non-vital rack wiring shall be stranded wire as specified herein, minimum wire size No. 19 AWG or multi-conductor cables as specified herein.

3. Rack wiring shall be neatly tied into compact bundles. The main bundles and branches shall be secured to the racks in a manner which shall preclude physical damage due to pressure of abrasion and prevent the wire weight from being supported by the wire terminations, connections, or plug connection. The arrangement of the wire bundles and cables shall be such that they do not interfere with visual inspecting, troubleshooting, or repair of the rack-mounted equipment.

D. Rack-to-Rack Wiring

All rack-to-rack wiring shall be routed via the overhead cable trays with one foot of slack between the cable tray and each rack to which the cable or wire is connected.

1. Vital Racks

Unless otherwise approved by the Engineer in writing, all rack-to-rack wiring for factory wired housings shall be accomplished using single conductors tied into bundles to form unjacketed multi-conductor cables. Unjacketed multi-conductor cables shall consist of individual conductors of size 16 AWG or larger wire and shall have a maximum tie spacing of six inches.

2. Non-Vital Racks

Unless otherwise approved in writing by the Engineer, all rack-to-rack wiring for non-vital racks shall be accomplished using single wire and multi-conductor cables as specified herein. Non-vital plug connectors use shall be minimized and only as required and as specified within these Specifications.

3. Non-Vital Racks to Vital Racks

Unless otherwise approved in writing by the Engineer, all wiring between non-vital racks and vital racks shall consist of single conductors, tied into bundles, between the non-vital rack and the vital rack connection points. These individual conductors shall consist of size 16 AWG or larger wire and shall have a maximum tie spacing of six inches.

E. Control and Maintainer's Panels

Ethernet and special application network wiring shall be as specified in Section 16866 – Non-Vital Systems and as shown on the Contract Drawings.

F. Entrance-to-Instrument Rack Wiring

Wiring from entrance racks to instrument racks shall be accomplished using stranded wire, as specified herein, minimum size No. 16 AWG, and as approved by the Engineer.

G. High Voltage Wiring

Internal wire used in circuits directly connected to the rails and internal wire used in circuits which operate at voltages in excess of 1000 volts shall meet the requirements of Section 16808 - External Signal Cable, as specified herein.

H. Energy Distribution

1. Vital Racks

Unless otherwise approved by the Engineer in writing, all wiring for energy distribution shall be accomplished using single conductor stranded wire as specified herein. Rack wiring shall be accomplished with solderless connections using stranded wire, minimum size No. 14 AWG.

Rack-to-rack wiring shall be accomplished with solderless connections using stranded wire, minimum size No. 14 AWG.

2. Non-Vital Racks

Unless otherwise approved by the Engineer in writing, all wiring for energy distribution shall be accomplished using single conductor stranded wire as specified herein. Rack wiring shall be accomplished with solderless connections using stranded wire, minimum size No. 16 AWG. Rack-to-rack wiring shall be accomplished using solderless connections using stranded wire, minimum size No. 14 AWG.

I. Conductor Sizing

All conductors must be sized per the National Electrical Code and to satisfy the load requirements of the equipment and systems provided, but shall not be smaller than the minimum conductor sizes specified herein.

3.02 TESTS

Internal wire and cable shall be tested as specified herein and in accordance with the requirements of Section 16898 – Signal System Tests of these Specifications.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment will be made for the work required under this Section. All costs in connection therewith shall be considered incidental to the work which it pertains.

END OF SECTION

SECTION 16856

ELECTRIC HEAT TRACING

PART 1 - GENERAL

1.01 DESCRIPTION

A. The work specified in this Section consists of furnishing, installing and testing of electric heat tracing system(s), complete with all required accessories, for the protection of pipe lines as shown on the Contract Drawings and hereinafter specified.

B. The General Documents, as listed on the Table of Contents and applicable parts of Division 1, General Requirements, and requirements of Section 16050, shall be included in and made part of this Section.

C. Pipe Lines to be Heat Traced:

1. General: All water piping exposed to outside air conditions.

1.02 APPLICABLE PUBLICATIONS

A. The publications listed below form a part of these Specifications to the extent referenced. The publications are referred to in the text by basic designation only. In case of conflict between provisions of codes, laws, ordinances, and these Specifications, including the Contract Drawings, the more stringent requirements will apply.

1. National Fire Protection Association (NFPA) Publication:

   70 - National Electrical Code

2. Board of Fire Prevention Regulations:

   527 CMR 12.00 Massachusetts Electrical Code

B. The equipment shall be designed, manufactured and tested in accordance with the applicable requirements of the following codes, standards and references.

- NEMA
- NFPA 70
- UL listed

1.03 GENERAL REQUIREMENTS

A. General requirements include those as specified herein. Materials not normally furnished by the manufacturer with this equipment are specified in:

Section 16050, "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK"

Section 16120, "WIRES AND CABLES"

Section 16450, "GROUNDING"

1.04 SUBMITTALS

A. Manufacturer's Data: Shall be submitted for the following:

1. Heat Tracing Cable
2. Temperature Controllers
3. Connection Accessories and Fittings

B. Shop Drawings: Shall be submitted for the following:

1. System(s) full isometric installation drawings including load charts.

C. Manufacturer's Instructions:

1. Manufacturer's installation, operation and maintenance instructions.

1.05 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Ship each unit or component securely packaged and labeled for safe handling in shipment and to avoid damage or distortion.

B. Mark each item, unit or component in accordance with applicable reference standard.

C. Store materials in secure and dry facility and in original packaging in a manner to prevent soiling, physical damage, wetting or corrosion prior to installation.

PART 2 - PRODUCTS

2.01 MATERIALS AND EQUIPMENT, GENERAL

A. All materials and components for the heat tracing system(s) shall be the product of a single manufacturer regularly engaged in the production of these materials and components for the intended application specified herein.

B. All materials and components shall, as a minimum, meet the requirements of UL where UL standards are established for those items, and the requirements of NFPA 70. All materials and components provided shall be new, unless specified otherwise or indicated.

C. The system(s) shall consist of factory assembled and tested materials and components shipped ready for field assembly. The system(s) shall include, but not be limited to, the following components:

- Electric Heat Tracing Cable
- Temperature Controllers

- Heat Tracing System Control and Monitoring Panel
- Connection Accessories and Required Fittings

2.02 ELECTRIC HEAT TRACING CABLE

A. Application: To provide "freeze protection" for piping systems where shown on the Contract Drawings. Freeze protection shall mean provision of adequate heating necessary to prevent freezing of the fluid contained within the piping when the ambient or surrounding temperature falls below 32°F (0°C).

B. Construction: The cable shall be composed of two No. 16 AWG copper buss conductors sized for the rating indicated, separated by a conductive matrix such that a constant heat output is provided for each linear foot of pipe at any temperature in the range specified, degraded by allowable voltage drop for the specified running length. In addition, the cable shall include a #16 AWG copper, fluorinated ethylene-propylene (FEP) insulated monitoring wire, which shall be used, in conjunction with an auxiliary relay, to monitor cable or system failure as specified hereinafter. The cable shall be of the self-limiting (self-regulating) type and fluorinated ethylene-propylene (FEP) insulated. Each cable run shall consist of a "heating" Section and "cold" section, all an integral part of the cable assembly and of a length consistent with the length of pipe including fittings and valves to be heat traced. The cable shall have the following ratings and characteristics:

- Maximum pipe maintenance temperature power "on": 150 degrees Fahrenheit
- Maximum intermittent exposure temperature-power "off": 185 degrees Fahrenheit
- Minimum installation temperature: Minus 60 degrees Fahrenheit
- Minimum bending radius: 1.25 inches
- Maximum earth leakage: 1 mA/100 feet at 240 vac
- Voltage rating of insulation: 600 volts
- Cable rating: Watts/foot as indicated
- Service voltage: As indicated

2.03 TEMPERATURE CONTROLLER(S)

A. General: For each heat tracing circuit provide one "control thermostat" for ON–OFF control and one "low temperature thermostat" for alarm condition when the pipe temperature falls below a set point, mounted in a NEMA 4 enclosure.

B. Construction: Each thermostat shall be industrial type, designed for the intended application, single pole-double throw, remote bulb type with six foot capillary encased in flexible stainless steel armor, rated for voltage indicated, single phase, 60 Hertz. The "control thermostat" shall close its contact(s) on falling temperature, the "low temperature thermostat" shall open its contact(s) on falling temperature. Each thermostat shall have an adjustable set point with 35°F to 235°F range calibrated dial.

2.04 HEAT TRACING SYSTEM CONTROL AND MONITORING PANEL

A. Application: Suitable for power distribution, control and monitoring of individual heat tracing circuits.

B. General: The panel shall be factory or shop assembled, wired and tested enclosure specifically designed for the intended application, suitable for wall mounting, containing, but not limited to, the following components:

- Circuit breakers for branch circuit protection
- Control relays
- Pushbuttons
- Indicating lights
- Terminal boards
- Nameplates

C. Construction: Panel shall be NEMA 4 enclosed with provisions for wall mounting, acceptance of electrical supply as indicated. The panel shall be equipped with required quantity of molded case ground fault interrupter (GFI) type circuit breakers as indicated. Wires and cables run within the panel shall be bundled together or harnessed and clamped in a neat, workmanlike manner. Wiring shall be minimum #14 AWG. Wires shall be tagged with wire numbers in accordance with applicable drawings. Provide terminal blocks for all field wiring. Terminals shall be factory assembled sectional terminal boards, channel mounted, 25 ampere minimum, box clamp type. Nameplates shall be fabricated from 1/8-inch thick laminated plastic with white letters on black background. Nameplates shall be 1-inch by 1-1/2-inches minimum with minimum 1/4-inch high normal block lettering. On top of the panel provide an identification nameplate to read: "HEAT TRACING SYSTEM CONTROL AND MONITORING PANEL". Provide nameplates for each switch, pushbutton, and pilot light.

D. Operation: Each heat tracing circuit shall be equipped with an individual control thermostat field pre-set to close at 45°F and open at 50°F and a low temperature thermostat field pre-set to open at 35°F. In the event of a heating cable failure or an overload condition that will result in tripping the branch circuit breaker, a panel mounted indicating light, identifying the heating cable circuit number and nature of trouble, shall be illuminated. Simultaneously a common alarm relay equipped with one type "C" contact, shall be energized for transmission of an alarm signal, via the SCADA system, to a remote location. In the event that the cable failure is not detected in the manner described above and the temperature continues to fall below the set point, a second panel mounted indicating light shall be illuminated identifying heating cable circuit number and the nature of trouble. Simultaneously the common alarm relay, described above, shall be energized. The panel shall be provided with pilot light test feature.

2.05 CONNECTION ACCESSORIES AND FITTINGS

A. The system shall be provided complete with manufacturer's recommended standard fittings, connection accessories, or other devices necessary to connect it to standard rigid steel conduit, junction boxes or other devices indicated on the contract drawings.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Installation shall comply with NFPA 70, the Massachusetts Electrical Code, and to the requirements specified

herein.

B. Install conduits, raceways as shown on the Contract Drawings and in accordance with Section 16050, "BASIC MATERIALS AND METHODS FOR ELECTRICAL WORK".

C. Make power and control wire connections as shown on the Contract Drawings, and in accordance with Section 16120, "WIRES AND CABLES".

D. Make ground connections as shown on the Contract Drawings, and in accordance with Section 16450, "GROUNDING".

E. Heat tracing cable shall be secured along the entire length of piping run with 3/4" wide polyester tape, banding the cable on 1'-0" centers.

F. Heat tracing cable shall be located at the 5 or 7 o'clock position on the pipe.

G. Install heating cable on the outside radius of elbows.

H. Where heating cable passes expansion joints, provide proper cable slack.

I. After completion of heat tracing, piping insulation shall be applied in accordance with Section 15250 "INSULATION".

3.02 INSPECTION AND TESTS

A. Field: Before and after the heating cable has been completely installed on the lines, but before pipes are insulated, the following tests shall be made:

- Check the continuity of the heating cable to be sure that the conductors have not been broken during installation.
- Megger test cables. The cables shall have not less than 10 megohms resistance from conductor(s) to sheath when measured with a 500 vdc megger, and with no decline in reading.
- Measure actual applied voltage and load current.
- Repeat the above tests and checks after pipe insulation is applied and installation is completed.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

A. No separate measurement shall be made for the Work of this Section.

4.02 PAYMENT

A. Payment will be at the unit price for the items listed below.

4.03 PAYMENT ITEM

Item No.	Item Description	Unit

1612.316	4 W PER FOOT PIPE TRACING	LF

END OF SECTION

SECTION 16866

PROGRAMMABLE LOGIC CONTROLLER

PART 1- GENERAL

1.01 DESCRIPTION

A. This Section specifies the final design, furnishing and installing of a complete Non-Vital Programmable Logic Controller (NVPLC) system to collect and transmit an indications to the new Train Status Panel initiated by existing panel control system based on track occupancy. The system shall include an NVPLC, Local I/O, Remote I/O and necessary Communications Busses and shall provide interface with existing equipment.

B. Architecture of this system and interconnection of elements is shown on the Contract Drawings. The Contractor may submit an alternative or variations to this architecture. However, the Authority is under no obligation to accept such alternatives or variations and will not be responsible for any additional costs or schedule impacts associated with the acceptance or rejection of said alternatives or variations.

C. Other work to be done under this Section shall include the preparation of design drawings for the intersystem circuits and software models that integrate the existing CIH equipment, NVPLC, the Train Status Panel, Local I/O, Remote I/O, and various data links.

1.02 QUALITY ASSURANCE

A. The Contractor shall certify, via environmental testing or test data therefrom, that all components of the non-vital system he proposes to furnish will successfully operate, in an environment consistent with the AREMA C&S Manual of Recommended Practices Section 11.5.1 for a Class C environment without the use of environmental controls. If the Contractor's proposed equipment is presently in service on the MBTA, in an identical application, this requirement shall be waved. The equipment currently in use on the MBTA in this application is the GE 9070 family of NVPLC working with GE Genius I/O.

B. All proposed components, assemblies and sub-assemblies, shall be fully factory tested in accordance with approved Factory Test Procedures. A Contractor's representative with intimate knowledge of the systems used and the specific application being tested shall conduct all testing as required by the Engineer.

C. Equipment furnished under this Section shall not be shipped until the Engineer has approved the Factory Test Reports in writing.

D. All components of the non-vital system shall be UL listed and shall be a FCC rated Class A device.

E. After the non-vital systems are installed and interconnected to the rest of the signal system, it shall be fully field-tested. A Contractor's representative with intimate knowledge of the systems used and the specific application being tested shall conduct all testing as required by the Engineer.

1.03 SUBMITTALS

A. The following plans and information shall be submitted for approval prior to fabrication and factory wiring of the non-vital systems equipment:

1. A comprehensive systems diagram (block diagram) describing all major components, functions interfaces, links, and associated software.

2. Catalog cuts and descriptive literature for all materials the Contractor proposes to use to implement the design as specified herein and as shown on the Contract Documents. As a minimum, this information shall be provided for each block in the Train Status Indication Panel Block Diagram.

3. Complete wiring and cabling drawings with all interfaces and data links including remote input/output functions and the equipment required for the interfaces and/or data links clearly indicated;

4. A complete and comprehensive operational description;

5. Complete circuit plans for all input and output functions performed by the system;

6. Plans showing arrangement and assembly with complete keyed part lists;

7. A complete Qualification Test Procedure for each component of the non-vital system that fully demonstrates that the equipment proposed meets all functional and environmental requirements;

8. A Factory Test Procedure designed to demonstrate that the system will be tested to verify that it performs all functions in accordance with these Specifications and Contract Drawings;

9. A Field Test Procedure designed to demonstrate that the system will be tested to verify that it performs all functions in accordance with these Specifications and Contract Drawings after installation;

10. Layouts for all racks containing non-vital systems equipment.

B. Complete application dependent software documentation including flow diagrams in symbolic or structured English format, ladder logic, and typical equivalent relay logic diagrams shall be submitted 60 days prior to factory tests.

C. One copy of all manuals and documentation required by these Specifications shall be submitted. Upon approval of the content, organization and format all documentation required by these Specifications shall be delivered to the MBTA.

D. Factory test reports complete with results for all tests shall be submitted prior to shipping equipment to the site.

E. Field test reports complete with results for all field tests shall be submitted prior to final acceptance.

1.04 DELIVERY, STORAGE AND HANDLING

A. The non-vital system components shall be properly installed in the rack at the manufacturer's point of shipment.

B. The Contractor and the Engineer or his representative shall inspect each item of the NVPLC system for shipping damage prior to installation. Any and all equipment incurring damage in transit, or caused by

mishandling or improper storage shall be replaced with no additional cost to the MBTA.

PART 2 - PRODUCTS

2.01 GENERAL

A. The non-vital systems equipment shall be designed to be mounted inside the Maverick CIH based on the existing space availability. The Contractor shall field verify the available space prior to designing NVPLC system. The Contractor shall furnish and install intersystem interface circuitry and equipment to be compatible with existing systems and equipment.

B. The electrical components, unless otherwise specified herein, shall be rated to operate at power, voltage and current levels twenty percent above and below that level which the components will be subject to in normal service.

C. All internal wiring, plug connectors, terminal boards, mounting hardware, special tools and apparatus required to effect a complete non-vital logic control system installation shall be furnished in accordance with applicable sections of these Specifications.

D. All hardware furnished under these Specifications shall consist of rigid components designed specifically for electrified rapid transit or similar harsh industrial environments.

E. All equipment supplied under this Section shall be sized to provide for 10% spare capacity without the need for additional hardware.

2.02 NON-VITAL PROGRAMMABLE LOGIC CONTROLLER (NVPLC)

A. The NVPLC system shall be of modular design with all components being housed in structurally secure racks or backplanes. Each module shall consist of one or more printed circuit boards attached to a durable plastic face assembly. Each module shall be mechanically keyed to prevent the accidental interchange of one module type for another. The card rack shall accommodate a wide range of modules that meet the Versa Modular Eurocard (VME) standard.

B. The NVPLC system shall be designed for rack mounting on existing instrument racks or wall mounted inside the CIH. All modules shall be accessible from the front and be easily replaceable. Each module shall contain its own identity and shall be keyed to prevent improper positioning.

C. The NVPLC system shall, as a minimum, contain modules of the types described herein and as shown on the Contract Drawings. Additional types of modules required for operation of the NVPLC system shall be furnished and installed as required. Wherever possible, all modules performing similar functions shall be interchangeable in order to minimize spare parts inventory.

D. The NVPLC backplane shall accept the integration of 3rd party VME modules with the particular characteristics of the Industrialized VME Bus Specification C.1.

E. The system shall be so designed that disconnection of field wiring is not necessary for replacement of assemblies. Universal removable terminal strips shall be utilized to connect field wiring to the individual circuit board assemblies.

F. The NVPLC shall be protected against all types of power surges as specified in Section 16897 –

Miscellaneous Components and Products.

G. The NVPLC shall utilize solid-state microprocessor technology and shall not require any off-line storage devices for operation or start-up. The operation of the system shall be programmed in solid-state memory. The processor shall perform the recognized signal industry entrance-exit functions as commonly supplied for a route-setting system. In addition, other functions as specified herein shall be part of this system.

H. The NVPLC shall receive 120VAC inputs from the contacts of existing relays within Maverick CIH presently lighting the existing panel, process them, and communicate panel lighting commands to remote I/O units installed within the new Panel through a remote I/O bus.

I. All hardware and software supplied with the development system shall be demonstrated to be completely compatible with the actual hardware supplied. Demonstration of compatibility must include backup documentation from the vendor of each type of hardware and software.

J. NVPLC Software:

1. The software package shall be fully compatible with PC's and laptops presently used by the MBTA Signal Division and shall be delivered with a license for 3 installations.

2. All application software shall be developed in ladder logic. A ladder logic development application shall be provided. This application shall enable the MBTA to design, test, simulate and execute changes to the NVPLC application software as well as adjusting the NVPLC configuration from the a laptop via serial link. No special communications boards shall be required in the laptop to communicate with the NVPLC with the exception of the required serial cards.

3. Programming equipment, location specific ladder logic lists and comprehensive user friendly manuals and maintenance/troubleshooting manuals shall be included in the software package.

4. Application Program Logic:

a. The ladder logic shall be a collection of programmed routines and functions necessary to perform the functions as specified herein and as shown on the Contract Drawings.

b. Ladder logic contacts shall be capable of being referenced any number of times within the application logic.

c. Ladder logic shall provide for multiple programmable timers and counters. Each timer shall have selectable time bases of 1.0 seconds, 0.1 seconds, or 0.01 seconds. The timer and counters shall have limits so as to avoid the need for cascading in order to implement the design.

d. Single precision, double precision, relational and floating-point arithmetic operations shall be provided by the program logic.

e. Table, move, conversion, bit and bit matrix data operations shall also be provided by program logic.

f. The ability to "dump" blocks of logic states with their associated time and date stamps an

external PC. The implementation of this "dump" shall occur during each scan cycle and shall have a minimal effect on the scan time.

K. Power Supply Modules

The NVPLC shall operate from a nominal 24 V dc battery system. The NVPLC power supply shall be equipped to operate under a voltage range of 19 V to 30 VDC.

L. Central Processor Unit (CPU)

1. The CPU shall be modular and shall not occupy more than one available slot when mounted in the system cabinet. The CPU module shall solve all application logic, store the application program and numerical values related to the application processes and logic, and interface to all I/O systems.

2. The central processing units shall contain the master clock/calendar function and clock/calendar shall be accessible by the application logic for date and time stamping of events.

3. Memory shall contain solid-state memory circuits programmed with the instructions for the system operation. The register values and application program shall be stored on battery backed Complementary Metal-Oxide Semiconductor (CMOS) static RAM. All timing functions shall be handled by the central processing unit from the stored program in CMOS. The memory module shall also be equipped with adequate Random Access Memory (RAM) for temporary data storage and retrieval.

   a. A minimum of 1 MB of application memory shall be available for the user program. Executive level operations performed by the CPU shall not consume application memory.

   b. There shall be a long life lithium battery used to maintain the contents of the CMOS memory in the CPU. The battery shall have a minimum life of six months while maintaining the memory status (loaded) and 6 years minimum while power is applied to the CPU and memory.

   c. The battery shall be enclosed in the CPU module and shall be capable of replacement with power applied to the NVPLC and without removal of the CPU. Dual battery jacks shall be provided.

   d. Visual indication of the battery condition shall be supplied as well as an entry in the fault table for the CPU.

M. System Diagnostics - The NVPLC shall be equipped with extensive self-diagnostic capabilities. These capabilities shall include but not be limited to:

1. Information on the status of the CPU, Memory, Communications, and I/O,

2. The ability to time stamp and log system and I/O faults into dedicated fault tables,

3. Faults shall have the ability to be configured in two levels: fatal or diagnostic. Fatal faults shall be logged and initiate fail-over while diagnostic shall only be logged,

4. All diagnostic information shall be accessible from the Maintenance PC or through a serial communications (maintenance) port for access by a laptop. The information available shall include the nature of the fault, the address and the timestamp,

5. The diagnostic information shall also be available to the application ladder logic.

N. Security - Passwords to provide differing levels of access privilege for the NVPLC's shall be available. Four levels of access privilege shall exist.

Access Level	Access Description
4	Change Password
3	Write Logic/Configuration, Override I/O
2	Write Data, Clear Fault Tables
1	Read PLC Only

The CPU shall be provided with a key switch to prevent alteration of the application program and configuration data through serial interfaces when the key is in the protected position.

2.03 NVPLC I/O AND ASSOCIATED I/O COMMUNICATIONS BUSSES

A. Two types of non-vital I/O are required for this project, Local (shown as NVPLC Direct I/O) and Remote. Communications between the NVPLC and the Remote I/O shall be via the remote I/O bus. Communications between the NVPLC and the Local I/O shall be via NVPLC back plane.. Local I/O, I/O resident in the NVPLC card rack, shall be utilized to receive 120VAC from existing relay contacts presently used for lighting existing panel. Remote I/O shall be utilized for NVPLC communication
A. with Train Status Panel.

B. Each I/O block shall be modular in design consisting of two components, the electronic assembly and terminal assembly. The terminal assembly provides for field wiring connection. Replacement of the electronic assembly shall not require the field wiring to be disconnected from the terminal block nor shall it require specialty tools to separate it from the I/O block. After the initial configuration is complete the electronic assembly shall be replaceable without requiring reconfiguration.

C. Indicators, visible from the front side of the block, shall be provided for the state of each individual I/O circuit on discrete I/O blocks. Additional indicators shall be included to provide general diagnostic and health information for the I/O block as a whole for all blocks (discrete and analog).

D. The terminal block portion of the I/O block shall accept one #12 gauge or two #14 gauge wires.

E. All I/O block addressing, monitoring and configuration shall be accomplished with a laptop via serial link. The option of protecting the block's configuration from modification shall be available via a setting controlled from a laptop connected via serial link.

F. Communications between the controlling NVPLC and the I/O blocks shall be via a proven reliable serial link. The physical connections between devices shall be made with the manufacturer recommended cable for the baud rate and communications requirements of the application.

G. The I/O block power supplies shall be designed to operate with the same voltage as that being controlled by the I/O block.

H. In combination with the capability for I/O distribution, the I/O system must offer automatic diagnostic capabilities for the system as a whole, for individual I/O blocks and for individual circuits. Diagnostic capabilities shall include the ability to monitor faults that are both internal and external.

I. All system, I/O block, and individual circuit faults detected by the automatic diagnostics shall be capable of being reported automatically to the NVPLC. Faults from individual I/O circuits may be selected for reporting on a circuit by circuit basis. The selection to report or not report a fault shall be made through the block's configuration.

J. All I/O blocks shall include a built-in self-test feature that automatically occurs and results in any detected faults to be reported to the NVPLC.

K. I/O blocks shall be available from the same product family and of the discrete type with control voltages available for all applications required on this project. All I/O associated with the NVPLC shall be either sink or source type. I/O that is both sink and source capable will not be accepted.

L. Remote I/O blocks mounted outside the CIH shall be mounted on an isolated equipment board inside the Train Status Indication Panel to protect the equipment from surges that may hit the panel where it is installed.

M. The manufacturer shall provide a hardware and software interface to the I/O blocks for the same manufacturer's NVPLC. The interface shall properly interpret all diagnostic data (faults) provided by the I/O system. The diagnostic data shall be time tagged as received from the I/O system then stored in the NVPLC's memory. A laptop, connected via serial link, shall have the capability to access the faults stored in memory and display them in an easy to read English language format.

N. The fault information must be available, in an easy to use manner, for use within the NVPLC's logic program.

A. The NVPLC's programming terminal shall be able to clear faults at the I/O blocks via the NVPLC and its interface to the I/O system. A faulted I/O circuit will resume normal operation upon clearing the fault.

B. The manufacturer shall provide a means of displaying and printing a chronological log of faults reported from the I/O system as they occur, are acknowledged and cleared.

O. The NVPLC shall have the capability to read I/O block configuration data from the I/O block. It shall also be capable of writing this information back to I/O block.

P. Discrete I/O Blocks:

1. Discrete input circuits shall be available that offer an option of operating as a standard input (recognizing only the on and off states from the field input device) or as a tri-state input (recognizing on, off and open circuit states from the field input device). If a circuit is selected to function as a tri-state input, a detected open circuit fault shall be reported automatically to the NVPLCs.

2. All discrete output circuits shall offer one of three options that will determine what happens to that particular output circuit when, for whatever reason, the I/O block stops receiving fresh output data from

the NVPLC. The three options shall be selectable as:

a. Hold Last State,

b. Default to the Off State,

c. Default to the On State.

3. Discrete output circuits shall be available that have a built-in diagnostic feature that checks for a minimum current to flow through the output circuit whenever the output is in the on state. If this minimum amount of current is not detected, a no load fault shall be automatically reported to the NVPLCs. The ability to disable this check for minimum current shall be available through use of a Laptop or hand held configuration tool.

4. No fuses shall be used in any of the output circuits. In lieu of destructive fuses, all discrete output circuits, except those that employ relays, shall have a built-in overload state. If this overload current is detected, the output circuit shall turn itself off and an overload fault shall be reported automatically to the NVPLC. The capability to disable this check for overload current through use of a Laptop or hand held configuration tool shall be available for high current loads.

5. All discrete output circuits, except those which employ relays, shall have a built-in diagnostic feature that checks for a maximum Short Circuit current through the output circuit whenever the output is in the on state. If this maximum amount of current is detected, the output circuit shall turn itself off and a short circuit fault shall be reported automatically to the NVPLC.

6. Discrete outputs shall be available that provide the ACTUAL output state to the NVPLC. This feedback information shall be based on output current and voltage and be provided in the form of an input that reflects the field-side state of the output.

7. Capability to test discrete outputs without changing the state of the connected load shall be available. The tests shall be accomplished by quickly pulsing the output to its opposite state while checking for the correct current and voltage changes. If the correct change in current/voltage does not occur, the appropriate fault shall be reported automatically to the controlling computer. The pulses shall be of a short enough duration to not affect normal loads. The option for disabling this pulse test on a block by block basis shall be available.

Q. I/O Bus Communications:

1. The NVPLC and the I/O blocks shall communicate via a reliable, high speed, peer to-peer serial link.

2. Cyclic Redundancy Check (CRC) type error checking shall be used for all data communicated on this link. Communications errors (bus errors) shall NOT prevent the I/O system from continuing its operation. If bus errors are encountered the incorrect data shall be rejected and the bus error reported to the NVPLC.

3. Isolation shall be provided between all devices connected to the communications bus. The

communications bus shall be able to withstand 1500-volt transients between itself and the I/O circuits in each I/O block.

4. There shall be NO active components in the serial cable path for the purpose of receiving, transmitting or amplifying the communications signal. Failures of any device on the communications bus shall not affect communications with other devices on the same bus.

2.04 MANUALS AND DOCUMENTATION

A. Unless the NVPLC system furnishedis presently used by the MBTA. All documentation shall be delivered in the form of 19 bound hardcopies (4 for the maintenance and engineering department and 15 for the training facility) and two (2) electronic copies on CD (.PDF format). The electronic copies shall come with the necessary software for viewing and updating the documentation by the MBTA.

B. All required documentation shall be delivered to the MBTA upon final approval of submittals and shall consist of the following:

1. Complete documentation of software development subsystems for application programming to allow the MBTA in-house modifications to the application logic by personnel with a signal engineer classification.

2. Deliver complete integrated circuit drawings of all boards to a component level and supply trouble-shooting procedures to a component level.

3. Deliver complete copies of all maintenance manuals for the installed NVPLC system, including specialty component/module documentation, complete with troubleshooting procedures and detailed parts lists. These manuals shall consist of two types, manufacturer generic and application specific. Both types shall be written so that an average, qualified technician is enabled by the reading thereof to maintain, repair, test and adjust the equipment. The application specific manuals shall include a complete description of the system operation, installation, alignment and adjustment procedures, and troubleshooting tables/logic charts to assist in locating malfunctions and locating failed components.

PART 3 - EXECUTION

3.01 INSTALLATION

A. All equipment shall be mounted in standard 19-inch shock mounted instrument racks or approved wall panels.

B. All wire connections to the equipment shall be via terminalized cable connectors.

C. All cables or wiring leaving the 19-inch shock mounted instrument racks shall be routed through rubber boots at the top of the racks and shall be neatly routed and securely fastened with tie straps.

D. The mounting shall provide for easy access to all test points, indicators, and adjustments.

E. Mounting height of NVPLC equipment within a CIH or room shall be restricted to an area between 1.5 feet and 5.5 feet above the finished floor.

F. Where slot(s) in a card rack are left unoccupied, the unoccupied sections of the card rack shall be covered with blank covers of similar manufacture to the face assembly of the modules provided. Additionally the rear of the card rack shall be enclosed with a removable cover to protect the back plane.

G. Each major component specified herein shall have a typed, or printed, name tag on a front plate of each rack and cabinet to clearly identify the component using the same wording as that appearing in the approved drawings.

H. All wiring and wire terminals shall be tagged in an approved manner.

I. The Contractor shall follow the following revision control procedure for NVPLC software or he may submit an alternate plan for approval:

1. At the beginning of the factory test, the approved program shall be labeled Revision 1.0 [Location]. At the completion of the factory test, the approved factory test version of program shall be labeled revision 2.0 [Location]. The checksum of Revision 2.0 shall be recorded prior to shipment and will be compared to the field test version prior to the start of filed testing. As field testing progresses, if changes are necessary, new revision numbers shall be assigned for each change (whenever the checksum changes). These numbers shall be based on incrementing the first decimal place for each change.

2. The program listing and EPROM shall contain a revision log detailing the revision history of the program. The plans and program listing shall be stamped with the stamp shown below. The EPROM shall store this information electronically.

NVPLC Application Program Revision Record					
Revision Number	Checksum	Date	Description	Test Engineer	Witness

3. At the end of the final cut-over the checksum shall be recorded for the accepted program and the program shall be labeled revision 3.0 [Location]. The final as-built plan sets shall contain the revision record with the last entry being revision 3.0 "As-Built".

4. At the end of each night/day of testing the Contractor shall provide the MBTA or its authorized representative an electronic copy of the software on floppy disk or CD-RW.

5. At the beginning of the factory test, the hardware configuration of the NVPLC system and all components shall be recorded. The information recorded shall include the following for each component:

   a. Part description and number
   b. Serial number and revision level

The Contractor shall follow this revision control procedure for NVPLC hardware or he may submit an alternate plan for approval.

J. The hardware configuration information shall be maintained as comments in the program listing as well as on a plan in the plan books. It shall be updated with any changes and each update shall include a clearly worded reason for the change.

3.02 FACTORY TESTING

A. The NVPLC system shall be tested in accordance with the approved Factory Test Procedure and with the applicable requirements of Section 16898 – Signal System Tests.

B. The Contractor shall make adjustments and shall correct defects as necessary to obtain proper operation. The Contractor shall be responsible for all additional costs related to additional testing due to faults in the application of the approved design.

C. All design changes found necessary to obtain proper operation shall be submitted to the Engineer for approval.

3.03 FIELD ACCEPTANCE TESTING

A. The Contractor shall prepare and provide a complete and comprehensive NVPLC system acceptance test procedure ("The System Acceptance Test"). The system acceptance test shall be sufficient for the Authority to determine to its reasonable satisfaction that the unit performs properly as a whole, including but not limited to, all operational functions.

B. The final system acceptance test shall commence after both the hardware and software have been successfully installed in the field by the Contractor.

C. The final system acceptance (in-service) test shall be deemed passed only if and when:

1. The system acceptance test has been successfully completed and no problems remain.

2. The Authority has successfully operated the unit for a period of not less than 30 consecutive days from the completion of final cut-over. During which time, a series of tasks and verification procedures have been performed as determined by the Engineer to be sufficient to enable the Engineer to determine that the unit operates in accordance with its functional specifications and its design specifications.

3. Throughout the period specified in the above item, the unit has not failed and no problems have been discovered.

D. In the event that problems are discovered during the system acceptance period or during any additional test period as provided herein, the time shall be extended an additional 30 consecutive days from the "Acceptance Date" date from which the Contractor has notified the Authority and said problems have been corrected.

E. The "Final Acceptance Date" shall be the day the system acceptance test has been passed pursuant to items H and I above.

F. The non-vital systems shall be tested in accordance with the requirements of Section 16898 – Signal System Tests and the manufacturer's recommended Installation Test Procedure as approved by the Engineer.

3.04 GUARANTEE.

A. For a period of 12 months commencing on the date of "Final Acceptance," the Contractor shall guarantee that the system is free from defects in design, material and workmanship and that the system shall operate in the manner intended as described in these Specifications, including but not limited to, the compatibility of the hardware with the software. The Contractor's guarantee hereunder shall extend to all elements of the system supplied pursuant to this Specification, whether supplied directly by the Contractor or not.

B. For the purpose hereof, a "design defect" shall include, but not be limited to the selection and arrangement of hardware, software and other related to similar elements of the system, whereby such inadequacies or weaknesses prevent a component of the system from providing fully satisfactory performance as intended by the design represented in the Contract Documents.

C. Depending upon the nature of the defect and the equipment concerned, it shall be rectified, including testing, promptly by the Contractor on site, free of any cost to the Authority, or returned to the Contractor for repair or replacement free of any charge whatsoever, or at the option of the Authority, it may be rectified by the Authority in accordance with the Contractor's instructions. In this latter event, direct labor and material costs only will be charged to the Contractor.

D. Work performed by the Contractor, or items replaced by him under his guarantee, shall be similarly under guarantee for an additional 12-month period.

E. Changes made to hardware or software under the guarantee shall also be made to spare items furnished or subsequently ordered from the Contractor.

F. Normal maintenance of the unit and repair of components by the Authority, or under maintenance contract, in accordance with the Contractor's instructions or accepted practice, shall under no circumstances relieve the Contractor of these responsibilities under this guarantee.

G. Where there is any conflict with the Contractor's standard guarantee, the guarantee statements in this Specification shall govern.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16869

TRAIN STATUS INDICATION PANEL

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies designing, furnishing and installing of a new Train Status Indication Panel for Maverick station.

B. The Train Status panel shall provide Blue Line operations personnel at Maverick Station with information regarding location of trains between Bowdoin and Orient Heights Stations by providing track occupancy indication.

C. The Panel shall be furnished complete with all required cable, raceways and associated hardware as specified herein and elsewhere within these Specifications.

D. New Panel shall be controlled by a Non-vital Programmable Logic Controller (NVPLC) complete with all associated communications busses. Existing panel controls within the Maverick CIH shall be modified accordingly.

1.02 QUALITY ASSURANCE

Factory and field testing of equipment covered by this section shall be in accordance with approved Manufacturer's Test Procedure and Signal System Tests Section of these Specifications.

1.03 SUBMITTALS

Submittals to be approved prior to the panel manufacturing shall include, but not to be limited to, the following:

A. A panel faceplate layout including all dimensions, tiles size, material, and tile holding grid.

B. Catalog cuts of all panel components with mechanical and electrical characteristics for each of the various types of panel components including panel application details.

C. A panel assembly drawings and associated sectional drawings for key mechanical elements.

D. A panel wiring diagram including component connections and grounding arrangements.

E. A panel lighting circuits including any modifications to the existing circuits proposed by the Contractor.

F. Site specific panel installation layout including all mounting hardware and load calculations.

G. Installation inspection procedure, factory and field test procedures.

1.04 DELIVERY, STORAGE AND HANDLING

Train Status Panel and all associated components and parts shall be properly crated at the manufacturer's point of shipment. The Contractor shall coordinate his work to schedule delivery of the

Panel for immediate installation. The Contractor shall provide for a storage facility approved by the Engineer if the panel delivered on site before scheduled installation. All damage caused by improper shipping, mishandling or storage shall be the Contractor's responsibility.

PART 2 — PRODUCTS

2.01. MATERIAL

A. The Train Status indication panel shall be constructed of square mosaic tiles made from the flame retarded material as manufactured by Mauell Corporation, ENTECH Corp., Siemens Ltd. or approved equal. Tiles shall be based on a metal grid.

B. The panel face shall be engraved with the track diagram existing at the time of submittal for approval.

C. Typical faceplate layout shown on the Contract Drawings shall be updated to reflect any revisions if required.

D. The track occupancy indicator lamps shall be red and shall be illuminated when the track circuit with which it is associated is occupied. Panel indicator lamps shall be replaced from the front of the panel. The indicator used shall be high intensity Light Emitting Diode (LED).

E. The Panel faceplate size, viewing angle and LED indicators' size shall provide clear visibility to a person standing on the station platform and shall be approved by the Engineer.

F. The Train Status indication panel shall be assembled in a dust-tight 14 gauge steel enclosure that is applicable for either wall or ceiling mounting. Terminal blocks rated for 600 volts shall be installed inside panel enclosure for wire terminations.

G. The front of the panel shall be protected by a hinged, clear—acrylic cover that is fitted with a locking facility for an Authority Standard padlock. Provisions shall be made to secure the cover in the open position to allow for inspection and maintenance.

H. Local lamp testing facilities shall be provided in the front and in the back of the panel. Remote lamp testing facilities shall be provided within CIH.

I. The Panel shall have provisions for ceiling and wall mounting. The contractor shall design furnish and install panel mounting facilities in accordance with panel manufacturer's recommendations.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Installation of Train Status Panel shall be in accordance with approved site-specific installation layout at approximate location of the existing panel. Final location shall be approved by the Engineer.

B. The Panel shall be suspended from the ceiling. The Contractor shall ensure that the structural elements supporting the panel are sufficient for the panel weight.

C. The Contractor shall install the Panel to provide clear visibility of indications to a person standing on the platform.

D. The visibility of the Panel shall not be obstructed by any signs or structures.

3.02 TESTS

Control and Indication panels shall be tested in accordance with approved Manufacturer's Factory and Field Test procedures and Signal System Tests Section of these Specifications.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement will be made for work required under this Section. All costs in connection therewith shall be included in the Contract Lump Sum Price for Signal and Communications System Modifications.

END OF SECTION

SECTION 16878

SIGNAL SYSTEM TESTS

PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the tests and inspections, which shall be performed to demonstrate that systems, subsystems, assemblies, subassemblies, components supplied under this Contract including modifications to existing systems are in compliance with the Specifications.

B. Tests and inspections shall be made during the progress of this Contract and after completing the installation of equipment. Tests and inspections shall consist of, but not be limited to, factory tests, circuit breakdown tests, wiring verification tests, continuity tests, resistance tests, voltage and current tests, time tests, operating tests, simulation tests, and other electrical and mechanical tests and inspections.

C. The work shall include the costs of the Contractor's personnel and any special equipment and assistance required to conduct all tests and complete the required documentation.

D. In the event that the system does not meet the Specification requirements, all necessary corrections shall be made and any and all tests or re-tests to prove compliance shall be included in the work, without any additional cost or time delay to this Contract.

E. The work shall include all disconnecting and reconnecting necessary for test purposes.

F. Test work specified elsewhere in these Specifications shall be construed as related to and inclusive with the testing described herein.

1.02 STANDARDS AND REGULATIONS

A. Standards – AREMA C&S Manual, Part 2.4.1 "Instructions for Inspection and Test of Signal Installations Before Placing in Service".

B. Regulations - Federal Railroad Administration, Rules, Standards and Instructions for Railroad Signal Systems, Part 236.

1.03 QUALITY ASSURANCE

A. All test procedures and inspection procedures shall be subject to the approval of the Engineer and shall comply with all FRA rules and regulations and AREMA recommendations.

B. The Contractor shall prepare and submit for approval a test plan outlining all tests required.

C. Test equipment of the proper type, capacity, range and accuracy shall be supplied by the Contractor to perform the required tests and inspections. This equipment shall be in good working order and properly calibrated at the time the tests or inspections are conducted.

D. Each component and unit of the wayside signal and traffic control system shall have an inspection performed at its point of manufacture and evidence of this inspection and acceptability shall be

indicated on the item where practicable.

E. All approved system and subsystem tests shall be completed prior to any operational testing to demonstrate that all installations meet these Specifications and design requirements.

F. The Engineer reserves the right to witness any or all tests and inspections in the Contractor's plants or other manufacturing facilities. The Engineer shall be advised a minimum of two weeks in advance of each factory test. When tests are to be conducted continuously as in a production line routine, the Engineer shall be advised two weeks in advance of the start of such tests and such notice shall indicate the duration period in which such tests will be conducted.

G. The Engineer reserves the right to witness any or all field tests conducted. The Engineer shall be notified in writing at least 48 hours prior to each field test. No part of the signal system shall be placed in service without an authorized representative of the Engineer being present and witnessing the in-service tests.

H. The work shall include all tests required to ensure the proper and safe operation of all systems and subsystems and to prove the adequacy and acceptability of the total installation specified herein. The tests to be performed shall cause each system and subsystem to be sequenced through its required operations, including the imposition of simulated conditions to prove that the installation complies with all specified failsafe requirements.

1.04 SUBMITTALS

The Contractor shall submit the following:

A. Within 60 days after receipt of Notice-to-Proceed, submit a Test Plan including:

1. Each test outline and a matrix showing each and all testing activities including time relationships for all activities required under this Contract and deemed necessary by the Contractor. Duration of tests and samples of test record forms shall be included.

2. The numbers of each type of component or unit to be tested for adequacy of design and quality control shall be identified.

B. Within 90 days after receipt of Notice-to-Proceed submit all detailed test procedures including but not limited to, the following:

1. Step-by-step instructions for the test personnel and personnel requirements.

2. All pertinent information regarding the simulating devices and the methods of simulation to be used.

3. A complete set of preprinted test data sheets for recording test results shall be part of test procedures submitted. These data sheets shall contain all information required to successfully perform the tests, including identifying acceptable ranges of test results and pass/fail criteria.

4. The detailed test schedule(s) for any cut-over and testing activities shall outline the Contractor's activities by task, expected duration and associated manpower requirements.

5. Within the projected schedule, a description of expected transportation impact should be addressed. Requests for track & power outages, flagging, etc. should be identified in sufficient detail.

6. The results of each test as herein specified, both factory and field shall be recorded and the completed data package including all forms and marked plans shall be furnished to the Engineer within 5 days of completion of the test. Certified test results shall also be furnished for tests performed by any subcontractors when such tests are required within this Specification.

7. All test reports shall be checked and signed by the Contractor prior to submittal to the Engineer.

8. Test reports shall document the calibration date of each instrument used during the test.

C. Upon completion of all tests specified herein, the Contractor shall submit a letter signed by an authorized representative, certifying that all tests have been performed.

PART 2 - PRODUCTS

2.01 SITE TEST EQUIPMENT AND MATERIALS

A. All test instruments and equipment necessary to conduct the tests specified herein shall be available, ready for use not less than one week in advance of test need. Ready for use shall mean properly matched for test parameters, properly calibrated, sufficiently supplied with leads, probes, adapters, stands, etc. necessary to conduct the particular test in a completely professional manner.

B. All temporary or interim test related materials, special tools, connections, jumpers, etc. shall be furnished and available not less than one week in advance of the test need.

PART 3 - EXECUTION

3.01 FACTORY TESTING

A. Confirmation shall be provided by the Contractor that all required factory tests of systems, subsystems, assemblies, subassemblies, and components supplied under this Contract have been performed in accordance with the test plan approved by the Engineer. These tests shall verify design and nameplate ratings and adequate and proper performance.

B. All systems, subsystems, and equipment shall be inspected and tested.

C. All components, other than those related to failsafe circuits, may be tested on a sampling basis. An approved number of randomly selected components or units from the manufacturing process shall be tested to ensure the adequacy and acceptability of all components and units produced.

D. When test results are not recorded on a test data plate affixed to the equipment or unit, certified test reports shall be furnished for each item at the time of delivery in a form and format suitable for regular office file record keeping.

E. Each component and unit shall be inspected at its point of manufacture and evidence of this

inspection and acceptability shall be indicated on the item where practicable.

F. All tests shall comply with and reference the appropriate sections of the FRA and AREMA manuals.

G. Prior to testing, the Contractor shall have identify any tests requiring a simulator and shall provide documentation within the submittal package relating to the circuit logic within the simulator and the operation of the simulator in the circuit under test.

H. Confirmation shall be provided by the Contractor that all required factory and product tests of cable, and cable system components supplied under this Contract have been performed. These tests shall verify design and specified ratings as well as adequate and proper performance. The Contractor shall be responsible for maintaining such records and having them available for inspection until such time as they are turned over to the MBTA upon final acceptance.

I. Certified test reports shall be furnished for each item at the time of delivery in a form and format suitable for regular office file record keeping.

3.02 FIELD TESTING

A. The field tests performed shall cause each installed system and subsystem to be sequenced through its required operations, including the imposition of simulated conditions, to demonstrate that the installation complies with all specified failsafe design requirements and operational functions.

B. The quality of the installation shall be demonstrated by field tests for continuity, insulation resistance, resistance of ground connections, circuit breakdown, visual inspection, and any other tests required by this Specification. These tests shall be performed prior to any operational testing of systems or subsystems.

C. The Contractor's test procedures shall consist of pre-printed data sheets or inspection sheets for each test. When completed by the field test personnel and checked for accuracy and completeness, the sheet shall be submitted as the test report.

D. When tests require specific meter or test instrument readings, the pre-printed data sheet shall show the allowable range of values, for each part of the test. The test report shall also contain a check-off system for each action and a blank space adjacent to the expected value in which to record the test readings.

E. The test report shall also contain a final description sheet on which the Contractor shall record discrepancies found and action taken. This documentation shall be furnished to the Engineer.

F. All test reports shall be dated and signed by the responsible employee of the Contractor or subcontractor on the day the test is performed. Space shall also be provided for the signature of the witnessing inspector.

G. The report shall show the specific test instruments used on each test, with the instruments identified by name, type, serial number, and calibration due date.

H. Should an error be discovered in field wiring and connections during field testing, that does not agree with the approved circuit plans, the Contractor may correct such errors. The Contractor shall

not, however, make any changes which affect the approved circuit(s), as designed, without prior written approval of the Engineer.

I. The Engineer will make all final determinations as to whether only a part, or the whole test, shall be re-run when any specific field test does not meet the requirements specified for the test.

J. Any changes made after completion of test procedure shall be retested in accordance with the applicable test procedure.

3.03 FIELD TESTS AND INSPECTION

A. General field tests shall include, but not be limited to, the following:

1. Ground verification test.
2. Energy distribution system and failure alarm checks.
3. Breakdown test of all vital circuitry.
4. Wiring verification of all non-vital circuitry.
5. Line circuit verification between wayside instrument cases and the CIHs.
6. Vital function tests.
7. Non-vital function tests
8. Operating tests.

B. Specific Field Tests

1. Resistance of Ground Connections

All grounding connections shall be tested to determine that the ground resistance is not greater than 15 ohms using the Ratio Ground Resistance test method. All ground connections shall be tested.

2. Insulation Resistance Tests

The testing of insulation resistance shall include tests to verify the following:

a. All wire and cable installed along the right-of-way and the wire and cable entering or leaving the wayside instrument housings shall be tested after installation to ensure that insulation of wires and cable and connected equipment meet the specified resistance value. A direct reading instrument, having a 0 megohm to 200 megohm scale range and a self-contained dc power supply rated 500 volts minimum to 1000 volts maximum, shall be used to measure the insulation resistance. Resistance between conductors and ground shall not be less than that specified in the Federal Railroad Administration Rules, Standards, and Instructions for Railroad Signal Systems, Part 236.108.

b. The insulation resistance of each conductor to ground and between each conductor and all other conductors in each multiconductor cable shall be tested. Power sources, made grounds, and connections to the rails shall be disconnected from the circuits during testing.

c. The point used as ground shall be the most convenient ground available.

d. Insulation resistance test values shall be recorded on the approved Insulation Resistance Record Forms and turned over to the Engineer upon his acceptance of this test requirement.

3. Crossbonding

The installed resistance of each 1000 kcmil crossbond cable shall not exceed 0.00016 ohms plus 0.000011 ohms for each foot of cable installed. The Null Balance method of testing shall be employed.

4. Vital Relays

a. All dc vital relays shall be tested for pick-up and drop-away values. These values shall be in accordance with field requirement values stated in Table I of AREMA Signal Manual, Part 6.4.1.

b. These measured values shall be recorded on the approved Relay Record forms and turned over to the Engineer upon his acceptance of this test requirement.

c. These tests shall be performed at the housing and room locations after final installation.

5. Energy Distribution

a. Energy-Off Tests

With all power off, the following checks and tests shall be performed. These shall include but not be limited to:

(1) All fuses shall be removed.

(2) Verify that circuit breaker size compares to that of approved circuit plans.

(3) All energy distribution shall be checked using resistance test instrument acceptable to the Engineer, to verify agreement with the approved plans.

(4) Compare wire gauges with those called for on the approved circuit drawings. All discrepancies in wire sizes shall be replaced with the proper size wire.

(5) During energy distribution breakdown, a wire count on each terminal, relay contact, etc. shall be taken to ensure that only the number of

wires called for on the approved circuit plans is present at each terminal, relay contact, etc. Any discrepancies found shall be corrected and additional wires, if found, shall be removed.

(6) Tags shall be verified for proper nomenclature and terminal location.

(7) Each energy bus shall be tested to all other energy buses to ensure that no crosses exist.

b. Energy-On Tests

Upon completion of the energy-off tests, the following checks and tests which shall be performed. These shall include but not be limited to:

(1) Insert fuses for power supply feeds and verify proper size according to the approved circuit drawings.

(2) Turn on energy feeds and test operation of power transfer for proper operation.

(3) Each ac voltage input shall be measured and recorded.

(4) Each power supply or charger output voltage shall be measured and recorded.

(5) Verify that the proper voltage is present at all distribution points.

6. Circuit Continuity Tests

All wire and cable installed by the Contractor shall be tested to verify the continuity of each conductor and that each conductor is connected to the proper terminal as shown on the approved drawings. Where parallel circuits exist, each parallel path shall be tested independently to verify the continuity of each path.

7. Vital and Non-Vital Circuit Breakdown

All circuits shall be checked for accuracy against the approved circuit drawings. Tests may be done with energy on or off and shall verify, but not be limited to, the following:

a. Point-to-point wiring.

b. A wire count of all field installed wires shall be made for each terminal, relay contact, etc. to ensure that only the number of wires called for on the approved circuit plans is present at each terminal, relay contact, etc. Any discrepancies found shall be corrected.

c. Verify tags and nomenclature where applicable.

d. Verify that all components, relays, resistors, etc. are the same as called for on the approved circuit drawings and located in proper positions.

8. Breakdown of Control Circuits

a. All circuits shall be tested in their entirety for the correct operation of and response to each contact on each circuit element, such as relays and contactors. Where parallel paths exist, the tests shall validate each path, and circuits shall be opened when required to ensure the proper test.

b. Each circuit shall be tested by simulating all operating conditions to verify that the circuit operates in accordance with the Specifications and approved plans.

9. Track Circuits

Each track circuit shall be tested in accordance with the Contractor's approved test procedure and shall include tests to verify the following:

a. Each track circuit shall be tested for defective insulated joint protection.

b. Each track circuit shall be tested for shunting sensitivity. A 0.06 ohm shunting strap shall be placed across the rails at the track feed, track receiver and all fouling points. The track circuit shall meet the requirement of FRA Rule 236.56, except with the track relay to be in the de-energized position with the 0.06 ohm shunt. This test shall be performed after the final track circuit adjustment has been made. Value of current required to pick up the track relay shall be recorded.

c. Each track relay shall be tested to assure that the proper phase relationship exists between the track energy being received and the local source used for comparison using the methods approved by the Engineer.

d. Each track circuit shall be tested for dropaway and pickup values with one impedance bond lead disconnected.

10. Signal Layouts

Tests shall be performed on all signal layouts. These tests shall include, but not be limited to the following:

a. Continuity check of field wires and verify all nomenclature.

b. Apply energy to signal lighting circuits and adjust all lamp voltages to 10 percent less than the lamp rating.

c. Break down signal clearing relay contacts and observe that proper signal aspect is displayed.

d. Sight signals for maximum visibility.

12. Line Circuits

The purpose of this test procedure shall be to verify the integrity of line circuits

between wayside instrument locations. All nomenclature shall be verified and line circuits tested for continuity.

13. Train Stops

The tests for the train stops shall include but not be limited to the following:

a. Mechanical distance and arrangements shall be checked against the approved installation plans. This shall include a check of proper stop arm height with an approved measuring device.

b. Contact closure and pressures shall be checked to be in agreement with the manufacturers requirements.

c. Checks shall be made to insure that the installed train stop operates at the manufacturer's recommended current requirements.

d. Lubrication shall be checked.

15. Running Rail Bonding

Electrical tests of running rail bonding and crossbonds shall be conducted and recorded as herein described.

a. Resistance of Welded Connections

The installed resistance of each welded bond shall be tested to verify that it does not exceed 0.000080 ohms.

b. Crossbonding

The installed resistance of each of 1000 kcmil crossbond cable shall not exceed 0.000160 ohms plus 0.000011 ohms for each foot of cable installed.

c. Impedance Bond Connections

The installed resistance of each pair of 500 kcmil impedance bond connecting cables shall not exceed 0.000160 ohms plus 0.000011 ohms for each foot of cable installed.

16. Exothermic Welds

a. The weld metal shall be of high electrical conductivity and shall have a minimum tensile strength of 39,000 pounds per square inch. The tensile strength shall be determined by tensile tests performed on ½-inch nominal diameter tensile specimens (without flaws)cast in graphite molds.

b. The casting of the test specimens shall be by the direct reduction of the exothermic mixture and the flowing of the weld metal into a graphite mold to form the ½-inch diameter specimens.

17. Automatic Signal Tests

Verify that automatic signals display proper aspects in agreement with the approved route and aspect charts.

18. System Tests

a. Tests shall be conducted to verify the integrity of the wayside signal system. These tests shall also include all tie-in interface signal control circuitry for all signaled tracks approaching and abutting the limits of this Contract.

b. Other system tests shall include, but not be limited to, the following:

(1) With traffic lined normal, a 0.06 ohm shunt shall be placed sequentially on each track circuit in the route to simulate train movement. The Contractor shall verify that all wayside signals, both automatic and controlled are displaying the proper signal aspects as indicated on the approved plans.

(2) All aspects observed during the progression of this test shall be recorded.

(3) Traffic shall be established in the reverse direction, for each route between adjacent interlockings, and the system shall be tested in a similar manner as described for normal direction operation.

(4) All design changes found necessary to obtain proper operation shall be submitted to the Engineer for approval.

19. Control Office to Wayside Interface

Upon completion of the wayside tests, a system test shall be performed to ensure continuity of operation of wayside equipment by the supervisory control system. This test shall consist of controlling all office wayside functions from the supervisory control console and the transmission back to the Control Office of all indications from the field stations. The functions to be tested shall include but not be limited to the following:

a. Indications to Supervisory Control Console

(1) Track circuit occupancy

(2) Train stop indications

b. All design changes found necessary to obtain proper operation shall be submitted to the Engineer for approval.

20. Power Tests

The following power checks and tests shall be made and recorded:

a. The voltage of the main power feeders shall be measured and recorded.

b. A check of all fuses shall be made for correct size and type.

c. All power supplies, battery chargers, and batteries shall be checked for correct setting and quantities.

d. Bus-to-bus checks shall be made to determine that no shorts, crosses or grounds exist.

PART 4 - MEASUREMENT AND PAYMENT

4.01 GENERAL

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16897

MISCELLANEOUS COMPONENTS AND PRODUCTS

PART 1 - GENERAL

1.01 DESCRIPTION

This Section specifies furnishing and installing miscellaneous components and products to be used on this Contract.

1.02 QUALITY ASSURANCE

A. All miscellaneous components and products shall be new and free of manufacturing defects, clearly and permanently labeled with value or type identification.

B. All electrical components shall be rated to operate at power, voltage, current, and temperature levels exceeding by 20-percent those which the components will be subject to in service, unless otherwise specified herein.

1.03 SUBMITTALS

Performance data or a sample of each type of component or product proposed as an equivalent to those herein specified shall be submitted.

The Contractor shall obtain the Engineer's written approval for any such equivalent type component or product he proposes to use.

PART 2 - PRODUCTS

2.01 CIRCUIT BREAKERS, FUSES AND FUSE CLIPS

A. Fuses and circuit breakers shall be of suitable capacities to protect the various pieces of signal apparatus from the effects of short circuits or overloads. All panels for utility power shall be equipped with Ground Fault Interruption (GFI) breakers on each branch circuit.

B. Circuit fuses shall be non-renewable, and shall be of the fiber-case, time-lag, fusion type. The circuit breakers and fuses shall be the correct size and rating for circuit current interruption and shall protect the electrical equipment and circuits from short-term and long-term overloads.

C. In dc branch circuits, where fusing is impractical, a protective resistance unit shall be furnished. All fuses shall be centrally located on the power distribution panel and power racks.

D. Fuse clips shall be so constructed that they shall retain their resilience under all installation and service conditions to assure a positive contact between the clips and the fuse.

2.02 SIGNAL POWER SECTIONALIZING SWITCHES

A. The Contractor shall design, furnish and install two Sectionalizing Switches to connect supplemental power from the new Maverick double ended substation to the Blue Line signal system.

B. The new sectionalizing switches shall be similar in design, construction, operation and maintenance to existing switches manufactured by MAC Products, Inc. (Model D9609, part No. 3098) and shall be fully compatible with existing signal power supply system.

C. The Sectionalizing Switches shall be installed on the side of, or in close proximity to, the Maverick CIH similar to existing installation and as approved by the Engineer. The switches shall be provided complete with all required material and mounting hardware necessary for installation in accordance with submitted and approved installation layouts.

D. The switch shall be remotely controlled solenoid-operated two pole, single throw rated 600 volts, 200 amperes, quick make and break, intended to isolate energized 480 volt, 1 phase, 60Hz circuits. The switch shall not open or close due to vibration rapid transit environment.

E. Each switch shall be mounted in a weather proof fiber glass enclosure with padlocking hinged cover and stainless steel hardware, for mounting with switch blades vertical. A latching bracket to hold the cover in the open position shall be provided.

F. The power unit for electrical operation of the switch shall be solenoid based. The power unit shall be capable of operating the switch, either to open or to close position within five seconds when energized by a supply of AC power at a voltage range between 102 volts to 138 volts, requiring not more than 5 amperes of operating current.

G. A positive mechanical-electrical interlock shall be provided to prevent remote electrical operation while manual operating means are in use. Each switch shall have contacts to provide indications when the switch is fully closed and when fully open. Neither indicating contact shall be made up when the switch is in any position other than fully open (±1/4 inch) or fully closed (±1/4 inch).

H. A removable handle shall be provided for manual operation of switch and shall be securely stored within each switch enclosure.

I. Switch shall be equipped with voltage sensing relays to indicate when the 480-volt line is energized. Each relay shall be enclosed in dust-proof covers.

J. The Contractor shall submit the following for approval prior to manufacturing:

1. Manufacturer's product drawings including all electrical schematics and mechanical assembly including switch enclosure.
2. Site specific installation details
3. Field installation and test procedure

K. Unless the proposed sectionalizing switch is identical to the existing switch, the Contractor shall also submit the following:

1. Performance data of the proposed sectionalizing switch.
2. Detailed material list and parts numbers
3. Factory test procedure and test results
4. Environmental requirements

2.03 RESISTORS

A. All resistors, other than those required for electronic circuits, shall be in accordance with AREMA Signal Manual Part 14.2.15.

B. Resistors for electronic circuits shall be in accordance with the applicable requirements of AREMA Signal Manual Part 14.2.40.

2.04 REACTORS

A. All reactors, other than those required for electronic circuits, shall be in accordance with AREMA Signal Manual Part 14.2.20.

B. Reactors for electronic equipment shall be in accordance with the applicable requirements of AREMA Signal Manual Part 1.4.20.

2.05 CAPACITORS

Capacitors, for electronic circuits, shall be in accordance with the applicable requirements of AREMA Signal Manual Part 14.2.40.

2.06 SIGNAL TERMINAL BLOCKS

Signal System terminal blocks shall be in accordance with the applicable requirements of AREMA Signal Manual Part 14.1.15.

2.07 SIGNAL TERMINAL BINDING POSTS

Signal System Terminal binding posts, other than those required for supervisory control circuits, shall be in accordance with AREMA Signal Manual Part 14.1.10.

2.08 TERMINAL POST INSULATORS

A. All terminal posts, located on terminal boards in the wayside cases and central instrument house used to terminate 120, or greater, ac volt circuits shall be provided with a protective insulator.

B. The type of insulator shall be individual for each terminal post, and shall be fire-resistant.

2.09 INSULATED TEST LINK

Insulated testing links shall be Type No.620 as manufactured by Railroad Accessories Corporation or Authority approved equal.

2.09 LIGHTNING ARRESTERS AND EQUALIZERS

Lightning arrestors and equalizers shall be mounted on three post porcelain or approved type base and shall be in accordance with AREMA Signal Manual Part 11.1.15.

2.10 TERMINALS FOR WIRES AND CABLES

A. All solderless terminals shall be in accordance with AREMA Signal Manual Part 14.1.1, or as

specified herein.

B. Terminals shall be of the solderless crimp-on type. Samples of all solderless terminals shall be submitted for approval.

C. All stranded copper wire shall be fitted with an approved type of terminal at all points where the wires are to be terminated on terminal binding posts.

D. The terminating means shall be of five types: (1) a lug for terminating heavy wires or signal power wires; (2) a solderless insulated terminal as manufactured by AMP, Inc. under the trade name of "Ring Tongue Plasti-Bond", similar to Catalog No. 35628, or approved equal, for terminating No. 16 and No. 14 AWG stranded wires; (3) a solderless insulated terminal similar to AMP Catalog No. 35627, or approved equal, for terminating insulated wires Nos. 12-10; (4) a solderless insulated terminal similar to AMP Catalog No. 324108 for terminating other stranded vital circuit insulated wires No. 20-16 AWG having a maximum diameter of 0.200 inches; (5) a solderless insulated terminal, AMP Catalog No. 320554, or approved equal, shall be furnished for No. 8 studs and AMP Catalog No. 320571 or approved equal, shall be furnished for one-quarter inch studs for non-vital circuit insulated stranded wires No. 22 - 16 AWG having a maximum diameter of 0.125 inches.

E. Where flag type terminals are required they shall be similar to AMP Catalog No. 322313, or approved equal, for terminating No. 16 and No. 14 AWG stranded wires. Other pre-insulated terminals shall be similar to those shown in AMP Product Bulletin No. 109-1.

F. The terminals shall be for attaching to the ends of the conductor in such a manner that the flexibility of the conductor will not be destroyed and the possibility of breakage at the terminal will be reduced to a minimum.

G. Terminals shall be for attaching to the wire with a tool made by the manufacturer of the terminal and recommended by him for the terminals being furnished.

H. The tool shall be equipped with a ratchet device to insure proper indentation of the terminal and which will not release until proper indentation is complete. Three such tools shall be furnished by the Contractor.

2.11 TAGGING FOR CABLES, WIRES AND EQUIPMENT

A. Except as otherwise specified in this Section, both ends of each cable and each cable wire and all single wires that terminate in the wayside cases, junction boxes, switch mechanisms, central instrument housings on entrance racks, and any equipment of the signal system outside of such locations shall be permanently identified with a tag. Tags shall not obscure connecting links used between terminal binding posts. Tags shall be installed so that they may be read with a minimum of disturbance of the tags and wiring. Each conductor of the cable shall be rung out and identified before applying the tag.

B. Tags for wire and cable identification and for identification of transformers, resistors, reactors and other components shall meet the following requirements and shall be subject to the approval of the Engineer:

1. Sleeve Type Tags

Tags for identification of individual cable conductors and field-installed wires within the wayside cases and central instrument housings, switch mechanisms, switch layout junction boxes, base of signal junction boxes and similar applications shall be the sleeve type as manufactured by Raychem Corporation, Thermofit Marker System (TMS), W. H. Brady Co., Bradysleeve (XB-321, -322, -323), or approved equal. The application of the conductor nomenclature shall be in accordance with the manufacturer's instructions and shall result in a permanently bonded and legible identification.

2. Flat Plastic Tags

a. Tags for identification of vital relay plug boards, individual transformers, resistors, reactors, terminals, and other miscellaneous components within the wayside cases, central instrument housings and outside terminal cases and snowmelter cases shall be the flat plastic laminated type.

b. These tags shall be one and one-half inches long by three-quarter inch wide with one, five-sixteenth inch hole located in the center of the width. The distance from the edge of tag to the hole shall be approximately nine thirty-seconds of an inch. The untreated tag shall be milk white "vinylite", or approved equal.

c. The identifying nomenclature space shall allow for three rows of lettering, and the tag material shall be capable of receiving typed-on characters by conventional means. The height of the lettering shall be not less than one-eighth inch.

d. After lettering, both the face and back side of the tag shall be covered with a clear plastic coating, "vinylite", or approved equal, of at least one hundredth of an inch thick.

e. The nomenclature applied to tags to go on entrance racks and boards shall show the terminal post identification on the top line. The functional nomenclature shall appear on the bottom line, or, if required, on the middle and bottom lines. The terminal posts shall be identified by geometry coordinates, such as rack, row and post number.

3. Wrap Around Tags. Tags for identification of the individual wires of plug-in relays, within the signal instrument house and the wayside cases shall be the wrap around, self-adhesive type.

4. Flag Marker Tags. Tags for identification of individual wires of shelf-mounted relays and wires and conductors in junction boxes shall be flag marker tags of the miniature locking type.

2.12 PRESSURE SENSITIVE LABELS

A. The rows and columns on entrance racks shall be identified by pressure-sensitive labels bearing the geometric coordinates.

B. Wires on plug-in vital relays shall be identified by the contact to which they are applied. These

tags shall be wrap-around self-adhesive type.

2.13 HARDWARE

All mounting hardware exposed to the elements and used for signal equipment, cases, conduit, hangers, brackets, clamps, etc., shall be hot-dip galvanized, except as otherwise approved by the Engineer.

1. Galvanizing

   a. The hot dip process of galvanizing shall be used. All parts shall be pickled so that all scale and adhering impurities will be removed. The zinc coating shall be of commercially pure zinc, and shall be continuous and thorough. It shall not scale or blister or be removable by any of the processes of handling or installation. The finished surface shall be free from fine line cracks, holes, or other indications of faulty galvanizing. It shall be smooth and free from adhering flux and other impurities. The edges and ends of parts shall be free from lumps and globules. Parts shall be coated with at least two ounces of zinc per square foot of galvanized surface, after all bending, cutting, drilling, and final fabrication.

   b. In order to avoid destruction of resilience encountered in the hot dip process of galvanizing, all lock-washers shall be cadmium plated.

2. Cadmium Plating

   a. All nuts, bolts, and washers used for the mounting of equipment within finished enclosures shall be cadmium plated or stainless steel. As an alternate, the Contractor may submit another type of plating or non-corroding metal for the Engineer's approval.

   b. Cadmium plating shall be an impervious, dense, hard, fine grained, continuous, closely adhering coating of commercially pure cadmium, free from capillaries and shall completely cover the surface of the part in a smooth, bright layer. Plating on raised or prominent portions shall show no evidence of blackness or loose crystalline structure. It shall have a minimum thickness of six tenthousandths of an inch and shall withstand the salt spray test for at least 1000 hours or an equivalent test approved by the Engineer.

2.14 CONDUIT

1. Rigid

Rigid conduit shall be used as herein specified and shown on the Contract Drawings. The types of rigid conduit to be used for the various applications shall be as follows:

a. Steel conduit shall be made of the best grade standard weight steel pipe protected inside and outside by a coat of hot dip galvanizing. Where elbows are used, they shall be long radius type. Steel conduits shall be protected in shipping and handling by approved thread protectors.

b. Fiberglass reinforced epoxy (FRE) conduit for exterior use shall be in accordance with the MBTA Standard Specification P-175.

c. Fiberglass reinforced epoxy (FRE) conduit for enclosed areas including tunnel shall be in accordance with the MBTA Standard Specification P-138E.

d. Schedule 80 PVC conduit will be allowed for temporary work in the vicinity of the station platform area.

2. Flexible Conduit and Hose

a. Hose for track circuit leads, switch-and-lock movements, electric locks, and snowmelter layouts shall be Braided Cordura Rayon, vari-purpose hose, internal tube neoprene cover, or Authority approved equal. The hose shall be clamped at both ends with stainless steel clamps. Clamps are not required for track wire risers.

b. Metallic Flexible Conduit. Where the Engineer permits the use of metallic flexible conduit shall be Type UA, or Authority approved equal.

3. Fittings

a. Approved PVC fittings shall be used for PVC conduit. All fittings for rigid steel conduit, it shall be of cast malleable iron, and shall be protected by hot-dip galvanizing.

b. Expansion joints for PVC conduit, if required, shall be Authority approved.

2.15 STAINLESS STEEL CLAMPS

Clamps for clamping hose at each end shall be stainless steel.

2.16 CABINET LOCKS, CAM LOCKS, PADLOCKS AND KEYS

A. Cabinet locks, cam locks, and keys shall be with key change in accordance with MBTA Commuter Rail standard for signal equipment requiring cabinet locks and cam locks. A minimum of 12 keys shall be included for cabinet and cam locks and 150 keys for each type of signal and switch padlock.

B. Padlocks for signal apparatus requiring padlocks shall be as follows, or Authority approved equal:

1. Switch Padlock : Model 0880 as manufactured by Sargent and Greenleaf for the MBTA complete with 13-1/2 inch chain.

2. Signal Padlock: Master Lock Model 19N 451 as manufactured for the with 13-1/2 inch chain.

3. Signal padlocks shall be furnished and installed for all housings, doors, and covers of signal equipment installed under this Contract. Switch padlocks shall be furnished and installed for trainman's access side of electric locks, power and hand-throw levers of switch-and-lock movements, telephone boxes, and manual control or emergency control boxes requiring access by train crews.

2.17 SEALING COMPOUND

Sealing compound for use in sealing cable entrances shall be in accordance with AREMA Signal Manual Part 15.2.15.

2.18 PAINT AND FINISH

All paint and painting procedures shall be in accordance with applicable requirements given in AREMA Signal Manual Part 2.4.30, where the AREMA requirements do not conflict with any requirement of these Specifications.

2.19 CABLE ENTRANCE PIPES

A. Cable entrance pipes for ground-mounted wayside signal cases shall be four (4) inch galvanized steel, three feet-six inches (3'-6") long, threaded on one end, reamed and chamfered and shall be furnished complete with one (1) locknut and one (1) bushing for each such pipe. One spare entrance pipe assembly shall be furnished for each ground mounted wayside case.

B. Cable entrance pipes for ground-mount signal instrument houses shall be six (6) inch cast-iron soil pipe three feet-six inches (3'-0") long with bell housing on one end, unless otherwise approved by the Engineer. One spare pipe shall be furnished and installed within each Signal Instrument House.

2.20 GROUND RODS, CLAMPS, AND WIRE

A. Ground rods shall be copper-clad steel, of the non-rusting type as manufactured by Copperweld Corporation, or approved equal. The rod shall be at least eight feet in length and at least five-eighths inch diameter.

B. Ground rod clamps shall be made of a cast bronze clamp body with non-ferrous set screws as manufactured by Copperweld Corporation or an approved equal.

C. Internal ground wire, from the equipment to the ground bus shall be insulated No. 6 or 10 AWG strandard copper wire, as specified within the detail sections of the Specification. Insulated ground wire shall be colored green.

C. A grounding bus of nickel plated hard drawn pure copper shall be provided in each signal instrument house and wayside instrument case. The minimum dimensions of this bus shall be eight inches by eight inches by one-half inch thick. A minimum of twelve, three-eighths inch holes shall be drilled and tapped in the bus and twelve, three-eighths inch by one-half inch long hex head nickel plated bronze studs with one washer each shall be installed.

2.21 LUBRICATION

Lubrication for switch tie plates for all switch-and-lock movement layouts installed by the Contractor shall be an approved graphite lubricant, similar to Dixon's Graphite "Railroad 60".

2.22 ENVIRONMENTAL PROTECTION

Projection as hereinafter specified, for machined- finished surfaces, threaded rods and nuts and other parts that are susceptible to rusting, shall be a corroding preventive compound, NO-OX-IDE No. 90918, or Authority approved equal. The product must have sufficient body to resist weather and rusting for at least six (6) months. Two gallons or equivalent weight shall be furnished by the Contractor.

2.23 COMMUNICATION SYSTEM PROTECTED TERMINAL BLOCKS

A. The protected terminal blocks furnished under this contract shall consist of pairs of brass binding posts imbedded in high impact resistant polyurethane. The number of pairs of binding posts shall be as shown on the Contract Drawings.

B. Each binding post shall be pre-wired to a two-electrode gas tube protector socket and shall be complete with two brass nuts and washers. The binding posts shall be sized to accept a minimum of three #19 AWG conductors.

C. Each terminal block shall be grounded with a #6 AWG insulated conductor to the case grounding grid, in accordance with Section 16876 of this Specification.

D. All protector sockets including spares, shall be equipped with gas tube arrestors, as specified in Paragraph 2.15 of this section.

E. Each pair of binding posts shall be marked with the cable designation and pair number of the pair terminated there.

2.24 COMMUNICATION SYSTEM GAS TUBE LIGHTING ARRESTERS

A. All gas tube lighting arresters furnished shall be two-electrode screw-in type. The arresters shall be UL approved for use on the protected terminal blocks furnished under this Contract.

B. The arresters shall have back-up air gap protection and shall be rated as Heavy Duty, as per REA Bulletin 345-83 (PE-80).

C. The gas tube lighting arresters furnished shall conform to the following specifications:

a.	DC Breakdown	300V
b.	Impulse Breakdown @10c v/u sec.	300 -750V
c.	DC Holdover	150 V
d.	Capacitance	5 pf
e.	End of Life Limits:	
	i) Insulation Resistance	- < = 1 Mohm
	ii) DC Breakdown	- < = 180 V
f.	Vented Back-up DC Breakdown	- < = 1600 V
g.	Maximum Impulse Discharge (8x20 u sec. Surge)	- 10,000 A
h.	AC Discharge Current (60 Hz)	- 65A, 11 cycle

2.25 COMMUNICATION SYSTEM SPLICES AND SPLICE ENCLOSURES

A. The Contractor shall furnish and install splices and splice enclosures within the in-line splice boxes as shown on the Contract Drawings. No direct buried splices in the T-screen communications cable will be accepted.

B. Splice Enclosures shall be non-metallic, re-enterable, type to allow for access to, and inspection of, the splice. The cable entrances to the splice enclosures shall be sized to admit the 25 pair

No. 19 AWG T-Screen cable, and the enclosure shall be large enough to accommodate the splices, shield bond, and aluminum tape, as required. Splice enclosures shall provide positive moisture and chemical resistance. All associated hardware and clamps shall be stainless steel.

C. Upon completion of the splice, splice enclosures shall be filled with a re-enterable encapsulating compound, so as to displace as near to 100% of the air within the enclosure as is practicable. The encapsulating compound shall be a fast curing polyurethane gel material that is compatible with the cable insulation and the enclosure material. It shall be transparent and shall retain adhesion throughout normal thermal expansion and contraction cycles.

D. Shield continuity shall be maintained through the splice with the use of tin plated brass shield connectors and copper bond braid as recommended by the cable manufacturer.

E. Separation of transmit and receive pairs shall be maintained throughout the splice by the application of overlapping layers of aluminum tape applied from the point where screen continuity is compromised.

F. The splices shall consist of groups of discrete self-stripping butt connectors housed in clear high-strength plastic. The discrete connectors shall meet the following specifications:

Connector Resistance Sensitivity to:	
Vibration	<= .10 Mohm change
Heat/Cold	<= .10 Mohm change
Stress Relaxation	<= .10 Mohm change
Humidity	<= .10 Mohm change
Wire Pull Out:	>= 70% Control Wire Breaking Strength
High Humidity Insulation Resistance:	>= 100,000 Mohm
Water Soak Insulation Resistance:	>= 1,000 Mohm
Dielectric Strength:	>= 3.0 KVAC

The Contractor shall have the connectors he intends to supply approved by the Engineer prior to ordering.

2.26 COMMUNICATION SYSTEM PUNCHDOWN BLOCKS

A. The Punchdown Blocks furnished under this Contract for cross-connection of communications equipment shall be 200 pair block factory pre-terminated with 10-pair block connectors.

B. The termination clips shall accept #20 - #26 AWG insulated conductors and #18 - #19 AWG skinned conductors.

C. Twenty 10-pair block connectors, affixed to a 21-position mounting bracket, pre-terminated to eight 50-pin male connector to help secure equipment cables.

D. Cable pair designations shall be marked and approved by the Engineer.

2.27 COMMUNICATIONS JUNCTION BOX

A. The Communications Junction Box shall be as specified in the MBTA Standard Communication Specification C-4 located in Technical Appendix U.

PART 3 - EXECUTION

3.01 INSTALLATION

All material and apparatus specified herein shall be installed in accordance with the detail of respective technical sections of these Specifications and in accordance with the Contract Drawings.

PART 4 - MEASUREMENT AND PAYMENT

4.01 METHOD OF MEASUREMENTS

No separate measurement will be made for work required under this Section.

4.02 BASIS OF PAYMENT

No separate measurement or payment shall be made for the work in this section, and all costs therewith shall be included in the work of Section 16801 BASIC SIGNAL TECHNICAL REQUIREMENTS

END OF SECTION

SECTION 16920

MOTOR CONTROL CENTERS AND MOTOR STARTERS

PART 1 -- GENERAL

1.01 DESCRIPTION

A. This Section specifies the furnishing and installing of motor control center, motor starters, current monitoring systems and equipment required to incorporate the Communication Programmable Logic Controllers (CPLC) for Unit Substation B2 and Ventilation Shaft B3 described in Section 16741 and 16050, Remote Terminal Unit for Shaft B2 Double-Ended Unit Substation as described in Section 16313, and in accordance with Standard Specification Section 16920 except as modified herein.

1.02 SUBMITTALS

C. See Section 16070, ELECTRICAL - MECHANICAL INTERFACE, Page 16070-2, Paragraph 1.04 for requirements for Coordination Drawings for Mechanical and Electrical work.

PART 2 – PRODUCTS

2.01 GENERAL

A. And identically wired (sequence wiring). Provide complete interconnecting control wiring as shown and as required for specified functions.

B. Enclosures shall be NEMA 12 Industrial Type.

C. Integrated equipment rating: 65,000 amperes RMS symmetrical.

D. Provide current monitoring circuit system for each tunnel emergency fan starter as described in Specifications Section 16314.

E. General Grounding Requirements: Ground Bus:

1. Provide a ground bus in motor control center compartments.

2. Connect the ground bus to system ground bus as shown on Contract Drawings.

3. Connect wall mounted ground buses to MCC ground bus.

F. Performance Criteria

1. General: The CPLC system shall allow remote control and monitoring of the Motor Control Center from 45 High Street. The CPLC shall monitor and control the Motor Control Center systems shown on the contract drawings and described on the attached points list in Appendix A. The CPLC on receiving a remote command shall provide all time delays,

alternate running patterns, or sequenced starts, necessary for correct running for the controlled equipment.

2.03 CONTROL UNITS

G. Manual Motor Starters: Designated units to include HAND-OFF-AUTOMATIC selector switch and pilot light in a single enclosure.

H. Magnetic Motor Starters:

2. Add the following sentence:
Provide magnetic overload relays for tunnel ventilation fan motors. Size overload relays for emergency tunnel ventilation fans based on 140 percent of the actual full load amperes for the motors being furnished. Overload relays shall be selected when the Fan Manufacturers have provided the full load current of the tunnel ventilation fan motors.

2.04 AUXILIARY DEVICES

A. Control Transformers

1. Add to first sentence the following:

and all indicated remotely located control devices.

B. Interposing Relays: Relays shall be of the momentary contact type, with 24 volt dc coil and 4 double pole, double throw contacts and manual operator. Contacts shall be silver cadmium oxide, gold flashed, rated 5 amperes continuous at 35 percent power factor, 120 volts, 60 Hertz, and suitable for 15 ampere load inrush (make) and for breaking 1.5 amperes. Pickup time shall be 13 ms maximum and dropout time 10 ms maximum. Coil resistance shall be of 650 ohms at 24 volts dc. Relay shall be of the long life design and mounted in a matching track mounted socket. Relays shall be similar to Square D Class 8501 Type RSD-14 Form M-1-24 Volts.

C. Terminal Strips: Strips shall be of the channel mounted type with pressure terminals for wire No. 10 AWG and smaller. Strips shall be rated 600 volts and furnished with white terminal marking strip for the complete length of the assembly.

D. Elapsed Time Meters:

1. Elapsed time meters shall be industrial panel board type, surface mounted, and a minimum dimension of 3.5 square inches.

2. Meters shall be non-reset 0 to 99,999.9 hours suitable for operation at 120 volts ac with an accuracy of plus or minus 2 percent ac.

3. Individual meters shall be provided for each tunnel emergency ventilation fan.

2.05 FABRICATION

C. Identification: A control center identification nameplate describing section catalog numbers and characteristics shall be fastened on the vertical wire center trough door of every section. Each control center unit shall have its own identification nameplate fastened to the unit saddle. These nameplates shall have suitable references to factory records for efficient communication with supplier. Each control center unit shall also have an engraved lamacoid nameplate fastened to the outside of the unit door for ease in identification and for making changes when regrouping units.

2.06 AUTOMATIC TRANSFER SWITCH

A. General

1. Furnish and install automatic transfer switch (ATS) having the ratings, options, enclosure, etc., indicated on the plans or noted herein. ATS shall have a "preferred power source selector switch".

2. The automatic transfer switch (ATS) shall be provided with full-rated overlapping neutral transfer contacts. The neutrals of the preferred and alternate power sources shall be connected together only during the transfer and retransfer operation and remain connected together until power source contacts close on the source to which transfer or retransfer is being made. The overlapping neutral transfer contacts shall not overlap for time duration greater than 100 milliseconds. A non-overlapping neutral transfer (fourth) pole shall not be acceptable.

3. When neutral conductors are to be solidly connected as shown on the plans, a neutral conductor terminal plate with full-rated AL-CU pressure connectors shall be provided.

4. Enclosure shall be NEMA 12 Industrial Type.

5. The ATS shall be rated to withstand the 65,000 amperes RMS symmetrical short-circuit current at the ATS terminals with the type of overcurrent protection shown on the plans.

6. The ATS shall be UL listed in accordance with the requirements of UL1008.

B. Construction and Performance

1. Mechanically-Held Transfer Switch

a. The transfer switch unit shall be electrically operated and mechanically held. The electrical operator shall be a single-solenoid mechanism, momentarily energized to minimize power consumption and heat generation. The operating transfer time shall be one-sixth (1/6) of a second or less.

b. The switch shall be positively locked and unaffected by voltage variations or momentary outages so that constant pressure is maintained at a constant value and temperature rise at the contacts is minimized for maximum reliability and operating life. The switch shall be mechanically interlocked to ensure only one of two possible positions – preferred or alternate.

c. All main contacts shall be silver composition. Switch shall have segmented blow-on construction for high withstand current capability and shall be protected by separate arcing contacts. ATS' utilizing components of molded-case circuit breakers, contactors, or parts thereof which have not been intended for continuous duty, repetitive switching or transfer between two active power sources are not acceptable.

d. Inspection of all contacts (movable and stationary), linkages and moving parts shall be possible from the front of the switch without disassembly of operating linkages and without disconnection of power conductors. A manual operating handle shall be provided for maintenance purposes. The handle shall permit the operator to manually stop the contacts at any point throughout the entire travel to properly inspect and service the contacts when required.

2. Microprocessor Control Module

a. The control module shall direct the operation of the transfer switch. The module's sensing and logic shall be controlled by a built-in microprocessor. The control module shall be connected to the transfer switch by an interconnecting wiring harness. The harness shall include a keyed disconnect plug to enable the control module to be disconnected from the transfer switch for routine maintenance.

b. The control module shall be completely enclosed with a protective cover and be mounted separately from the transfer unit. Sensing and control logic shall be provided on plug-in printed circuit boars. Interfacing relays shall be industrial control grade plug-in type with dust covers.

c. The control panel shall meet or exceed the voltage surge withstand capability in accordance with IEEE Standard 472-1974 (ANSI C37.90a-1974) and the impulse withstand voltage test in accordance with the proposed NEMA Standard ICS 1-109.

3. Operation

a. The voltage of each phase of the preferred source shall be monitored, with pickup adjustable from 85 to 100% and dropout adjustable from 75 to 98% of pickup setting, both in increments of 1%, and shall be fully field adjustable without the use of any tools, meters or power supplies. Repetitive accuracy of settings shall be ±2percentage or better over an operating temperature range of –20°C to 70°C. Factory set to pick up at 90% and drop out at 85%.

b. Single-phase voltage sensing of the alternate source shall be provided, with a pickup adjustable from 85 to 100% (and dropout fixed at 84 to 86% of pickup), and frequency sensing with pickup adjustable from 90 to 100% (and dropout fixed at 87 to 89% of pickup). Both pickup settings shall be fully field adjustable in 1% increments without the use of any tools, meters or power supplies. Repetitive accuracy of settings shall be ±2percentage or better over an operating temperature range of –20°C to 70°C. Factory set to pickup at 90% voltage and 95% frequency.

c. The control module shall include four time delays that are fully field-adjustable in increments of at least 13 steps over the entire range as follows:

1) Time delay to override momentary preferred source outages to delay transfer switch operation. Time delay shall be adjustable from zero to 6 seconds.

2) Transfer to alternate time delay shall be adjustable from zero to 5 minutes.

3) Retransfer to preferred time delay. Time delay is automatically bypassed if alternate source fails and preferred source is acceptable. Time delay relay shall be adjustable from zero to 30 minutes. Provide a toggle switch to manually bypass time delay on re-transfer.

d. A momentary-type test switch shall be provided to stimulate a preferred source failure. In addition, terminals for a remote contact shall open to signal the ATS to transfer to alternate and terminals for remote contacts which open to inhibit transfer to alternate and/or retransfer to preferred shall be provided.

e. A visual position indicator shall be provided to indicate ATS switch position. A prominent and detailed instruction plate shall be furnished.

f. One set of auxiliary contacts shall be provided rated 10 amps, 480 Vac, consisting of one contact closed when the ATS is connected to preferred and one contact closed when the ATS is connected to alternate. Output terminals to signal the actual availability of the preferred and alternate sources, as determined by the voltage sensing pickup and dropout settings for each source shall be provided.

g. Each switch shall be furnished with an operator's manual providing installation and operating instructions.

2.06 CIRCUIT BREAKER:

A. General

1. Furnish and install molded case circuit breakers having the ratings, options, enclosure, etc., indicated on the plans or noted herein.

2. Enclosure shall be NEMA 12 Industrial Type. Provide metal nameplates, containing a permanent record of breaker type, catalog number, and hp ratings.

3. The circuit breakers shall be 3-pole 600 volts grade and rated to withstand the 65,000 amperes RMS symmetrical short-circuit current.

4. The circuit breakers shall be provided in accordance with the UL requirement.

B. Construction and Performance

a. Provide breaker with operating handles and padlockable in the OFF and ON positions.

b. Each breaker shall be furnished with an operator's manual providing installation and operating instructions.

PART 3 -- EXECUTION

3.02 TESTING

A. Verify that all power and control circuits are connected as shown and as required.

B. Perform complete insulation and circuit continuity test. Insulation resistance to ground of all non-grounded conductors shall be not less than 10 Megohm.

C. Test equipment enclosure for continuity to the grounding system. Resistance of equipment enclosure to ground shall not exceed five ohms.

D. Test operation of circuits and controls, operating each control for a minimum of 12 times. Reversing starters shall be tested in each direction and multi-speed starters at each speed.

E. The transfer switch shall be subjected to the following factory tests:

1. The complete ATS shall be tested to ensure proper operation of the individual components and correct overall sequence of operating transfer time, voltage, frequency and time delay settings are in compliance with the specification requirements.

2. The switch subjected to a dielectric strength test per NEMA Standard ICS 1-109.21.

3. The Contractor shall pay for all travel, lodging and meal expenses for three (3) representatives of the Authority to attend the factory witness testing of the tunnel ventilation and the motor control center.

PART 4 - MEASUREMENT AND PAYMENT

4.01 MEASUREMENT

A. No separate measurement will be made for the work in this section but all cost shall be included in the pay item TUNNEL VENTILATION SYSTEMS which will be paid for under a lump sum basis furnished, installed, and tested complete in place as shown on the plans and as specified herein.

4.02 PAYMENT.

ITEM NO.	DESCRIPTION	UNIT
1586.040	TUNNEL VENTILATION SYSTEMS	LS

END OF SECTION

SECTION 16951

POWER SYSTEM STUDIES

PART 1 – GENERAL

1.01 DESCRIPTION

A. This Section specifies the furnishing of short circuit studies, protective device evaluation studies, protective device coordination studies and relay settings.

1. The studies shall be certified by an independent registered professional electrical engineer registered in the Commonwealth of Massachusetts.

B. The studies shall include, but not be limited to, portions of the electrical distribution system from the 15 kV normal power sources at the Airport Switching Station, Maverick Station B3 and B2 Ventilation Plant to and including the 480 distribution system down to the 120 V ac level for the electrical distribution system shown on the MBTA Spider Diagram for this project. Normal system connections and those which result in maximum fault conditions shall be included in the study.

C. The studies shall be performed by the manufacturer supplying the protective devices, including breakers and protective relays.

D. The studies shall be submitted by the Contractor prior to receiving final approval from the Engineer for shop drawings on the power distribution equipment shop drawings.

1. If formal completion of the studies causes delay in equipment manufacture, approval may be obtained for a preliminary submittal of sufficient study data to ensure that the information indicating device ratings and characteristics will be satisfactory.

E. A load flow study and voltage drop to the farthest point on the system shall be performed.

1.02 DATA COLLECTION FOR THE STUDIES

A. The Contractor shall provide the required data for preparation of the studies. The switchgear manufacturer shall furnish the Contractor with a listing of the required data immediately after award of the Contract.

B. The Contractor shall expedite collection of the data to assure completion of the studies as required for final approval of the distribution equipment shop drawings and/or prior to release of the equipment for manufacture.

C. Characteristic data shall be derived from actual, applicable components obtained from the approved shop drawings.

D. The Contractor shall coordinate with the Engineer in obtaining short-circuit data from the Authority.

1.03 SHORT CIRCUIT STUDY AND PROTECTIVE DEVICE EVALUATION STUDY

A. The short circuit study shall be performed with the aid of a digital computer program and shall be in accordance with applicable IEEE and ANSI standards.

B. The study input data shall include the power company's short circuit contribution, resistance and reactance components of the branch impedance's, the X/R ratios, base quantities selected and other source impedance's.

C. Short circuit close and latch duty values and interrupting duty values shall be calculated on the basis of assumed 3-phase and single phase bolted short circuits at each switchgear bus, low voltage motor control center, distribution panelboard, pertinent branch circuit panel and other significant locations through the system. The short circuit tabulations shall include symmetrical fault currents, and X/R ratios. For each fault location, the total duty on the bus, as well as the individual contribution from each connected branch, shall be listed with its respective X/R ratio.

D. A protective device evaluation study shall be performed to determine the adequacy of circuit breakers, molded case switches, automatic transfer switches, and fuses by tabulating and comparing the short circuit ratings of these devices with the calculated fault currents. Appropriate multiplying factors based on system X/R ratios and protective device rating standards shall be applied. Problem areas or inadequacies in the equipment due to short circuit currents shall be corrected, at no additional cost to the Authority.

1.04 PROTECTIVE DEVICE COORDINATION STUDY

A. A protective device coordination study shall be performed to provide the calculations and logic decisions required to select or to check the selection of power fuse ratings, protective relay characteristics and settings, ratios and characteristics of associated current transformers, and low voltage breaker trip characteristics and settings. The studies shall be in accordance with applicable IEEE and ANSI standards, and satisfy the requirements of the National Electrical Code.

B. The coordination study shall include, but not be limited to, medium and low voltage classes of equipment from the utility service connection protective devices to and including the largest rated device in the low voltage motor control centers, panelboards, down to typical 120 V ac branch circuits. The phase and ground overcurrent protection shall be included, as well as settings of adjustable protective devices.

C. The time-current characteristics of the specified protective devices shall be drawn on log-log paper. The plots shall include complete titles, representative one-line diagram and legends, significant motor starting characteristics, complete parameters of transformers, complete operating bands of low voltage circuit breaker trip curves and fuses. The coordination plots shall indicate the types of protective devices selected, proposed relay taps, time dial and instantaneous trip settings, transformer magnetizing inrush and ANSI transformer withstand parameters, cable thermal overcurrent withstand limits and significant symmetrical and asymmetrical fault currents. All restrictions of the National Electrical Code shall be conformed to and proper coordination intervals and separation of characteristic curves shall be maintained. The coordination plots for phase and ground protective devices shall be provided on a system basis. A sufficient number of separate curves shall be used to indicate the coordination achieved.

D. The selection and settings of the protective devices shall be provided separately in a tabulated form

listing circuit identification, IEEE device number, current transformer ratios and connection, manufacturer and type, range of adjustment and recommended settings. A tabulation of the recommended power fuse selection shall be provided for the medium voltage fuses where applied in the system.

E. Discrepancies, problem areas, inconsistencies or inadequacies shall be corrected, at no additional cost to the Authority.

1.05 STUDY REPORT

A. A preliminary report shall be submitted to the Engineer for review and approval.

B. The results of the power system studies shall be summarized in a final report.

1. The report shall be prepared and stamped by a professional electrical engineer registered in the Commonwealth of Massachusetts.

2. Six bound copies of the final report shall be submitted to the MBTA for their review.

C. The report shall include the following sections:

1. Description, purpose, base and scope of the study and an overall single line diagram of the power system which is included within the scope of the study.

2. Tabulations of circuit breaker, fuse and other protective device ratings versus calculated short circuit duties, and commentary regarding the same.

3. Protective device time versus current coordination curves, tabulations of relay and circuit breaker trip settings, fuse selection and commentary regarding the same.

4. Fault current calculations including a definition of terms and guide for interpretation of computer printout.

5. Load flow study.

6. Voltage drop to the furthest point shown on the Drawings.

D. One copy of the final report shall be submitted to the Power Company for their review.

PART 2 – PRODUCTS

NOT USED

PART 3 – EXECUTION

NOT USED

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. No separate measurement will be made for the work under this section but all costs shall be included for payment in the lump sum pay item TUNNEL VENTILATION SYSTEMS, complete in place as specified herein and shown on the contract drawings.

4.02 PAY ITEMS

ITEM NO.	DESCRIPTION	UNIT
1586.040	TUNNEL VENTILATION SYSTEMS	LS

END OF SECTION